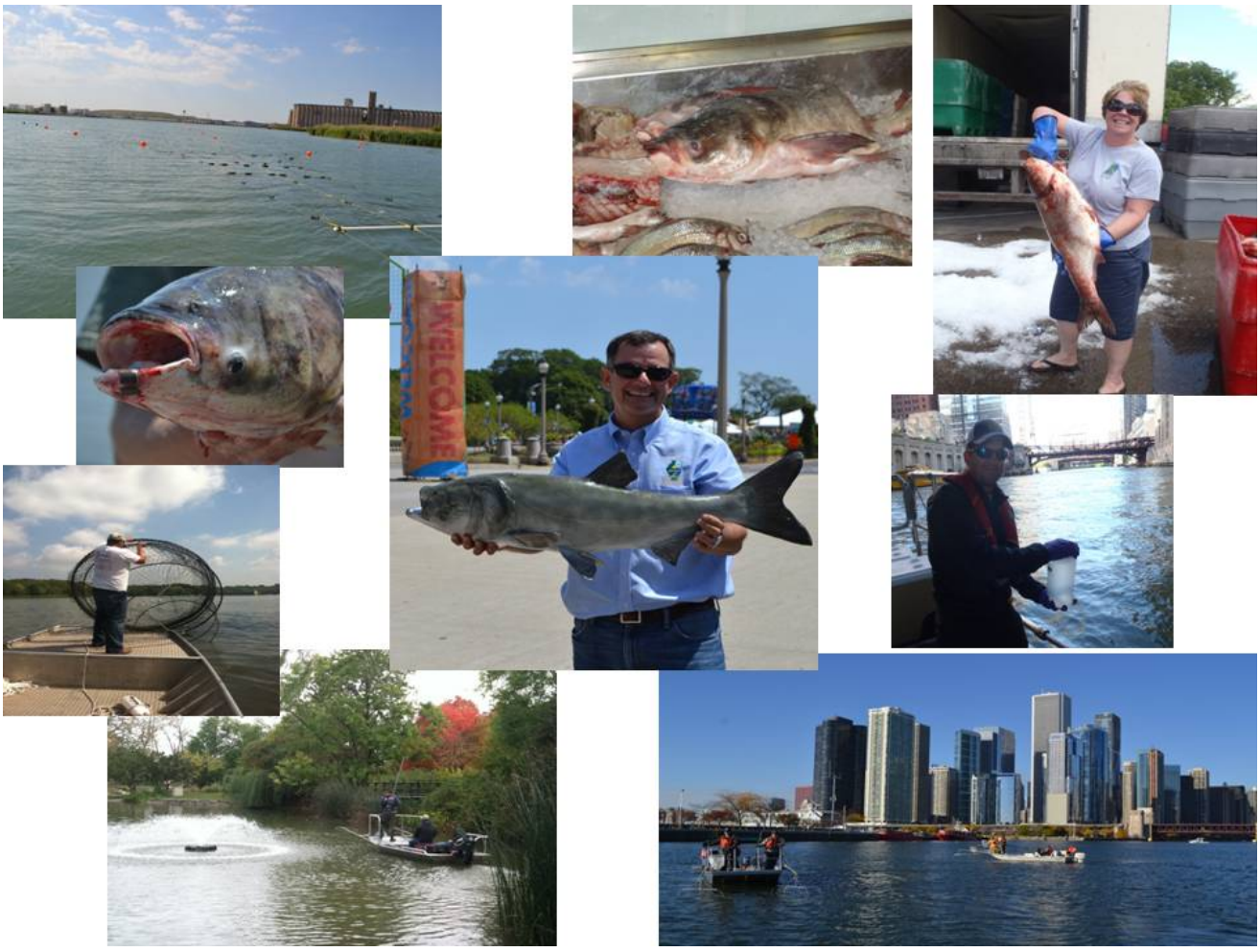
Asian Carp Regional Coordinating Committee

Monitoring and Rapid Response Workgroup

2012 Asian Carp Monitoring and Rapid Response Plan Interim Summary Reports

May 2013



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

ACKNOWLEDGEMENTS

This compilation of interim summary reports for projects included in the 2012 Asian Carp Monitoring and Rapid 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, and Metropolitan Water Reclamation District of Greater Chicago for supporting or assisting with field work during 2012 Asian carp monitoring, removal, and rapid response efforts. This and earlier versions of this document have benefitted from reviews by K. Baerwaldt, K. Irons, T. Hill, R. Simmonds, S. Finney, A. Parker, J. Stewart, M. Shanks, and J. Zeigler. M. McClelland, B. Ruebush, V. Santucci, and K. Irons provided pictures for the cover. M. McClelland assembled this compilation of interim reports.

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2012 Monitoring and Rapid Response Plan Interim Summary Reports

EXECUTIVE SUMMARY

The latest version of the Asian Carp Monitoring and Rapid Response Plan (MRRP) was prepared by the Monitoring and Rapid Response Workgroup (MRRWG) and released by the Asian Carp Regional Coordinating Committee (ACRCC) in May 2012. It included 18 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 MRRP 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 2012 MRRP 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 plan for the coming year.

This document is a compilation of interim reports for the 18 individual projects found in the 2012 MRRP. The reports include summaries of activities completed during the 2012 and, in some cases, 2010-11 field seasons. Most reports are preliminary in nature and contain preliminary data summaries, analyses, and interpretations. Whereas results and conclusions may change as more data is collected and analyses are refined over time, they still provide a scientific basis for proposed modifications to the 2013 MRRP 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 barrier system.

- Estimated over 9,600 person-hours spent sampling at fixed sites upstream of the electric barrier system in 2010, 2011 and 2012.
- Estimated 3,713 person-hours spent sampling at fixed sites, and 3,805 person-hours spent sampling in random areas upstream of the electric barrier system in 2012
- 533 hours spent electrofishing and 165.9 miles of trammel/gill net deployed at fixed sites in 2010, 2011, and 2012 and random areas in 2012.

- 192 hours spent electrofishing and 81.7 miles of trammel/gill net deployed at fixed sites and random areas in 2012.
- Sampled 192,763 fish representing 67 species and two hybrid groups during electrofishing and trammel/gill netting at fixed sites in 2010, 2011, and 2012 and random sites in 2012.
- Sampled 99,234 fish representing 63 species and two hybrid groups during fixed and random electrofishing and trammel/gill netting 2012.
- No Bighead or Silver Carp were captured or observed during fixed site and random area electrofishing and netting in 2012.
- Based on the extensive sampling performed upstream of the electric barrier system, and the need for more sampling downstream of the electric barrier system, we recommend reducing the frequency of electrofishing at fixed sites and random areas upstream of the electric barrier system and increasing sampling downstream of the electric barrier system

Strategy for eDNA Monitoring in the CAWS and Upper Des Plaines River (11) – This project presents a strategy for bi-weekly eDNA monitoring in the CAWS upstream of the electric barrier system.

- 2012 bi-weekly eDNA monitoring collected 1,196 samples from May through October, in addition to 14 samples collected from the International Harborside Golf Course lake.
- 153 samples from upstream of the electric barrier system were sequenced as positive for Silver Carp DNA and 4 samples were sequenced as positive for Bighead Carp DNA.
- An estimated 428 person-hours were spent collecting and filtering 2,420 liters of water in 2012.
- Consecutive eDNA positives triggered two Level I Rapid Response actions in Lake Calumet during July and October 2012 and one Level I Rapid Response action in the North Shore Channel during October 2012. No Asian carp were sampled or observed during conventional gear sampling. All eDNA samples collected immediately before the events returned positive DNA detections for Silver Carp.
- Recommend discontinuing eDNA as a trigger for Rapid Response Actions until further refinement of the technique is accomplished. Sampling events above the electric barrier system should occur on two snapshot occasions, one in spring and one in fall, with four sample events below.

Larval Fish and Productivity Monitoring (19) – Sampling for fish eggs and larvae and productivity monitoring took place biweekly from May - October 2012 at 10 sites downstream of the electric barrier system (LaGrange to Brandon Road pools) and 4 sites in the CAWS upstream of the electric barrier system.

- Over 600 larval fish samples were collected from 13 sites across the length of the Illinois Waterway during May – October, 2012
- 25,612 larval fish were collected in 2012, including 396 larval Asian carp
    - Larval Asian carp were only collected in the LaGrange Pool in May – June
    - A single Asian carp egg was collected at Henry (Peoria Pool) in May
- 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.
- Asian carp eggs and larvae have never been documented in the Upper Illinois River (above Starved Rock Lock and Dam) or CAWS.
- Recommend continued monitoring to document the spawning location and threat that spawning Asian carps present.

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

- Sampled for young Asian carp in 2010, 2011, and 2012 throughout the CAWS, Des Plaines River, and Illinois River between river miles 83 and 334 by incorporating targeted sampling as well as mining data from several ongoing monitoring projects.
- Sampled with active gears (pulsed-DC electrofishing, small mesh purse seine, midwater trawl, beach seine, and cast net) and passive gears (experimental gill nets, mini-fyke nets, and trap nets). Completed 1,070 hours of electrofishing across years and sites.
- Examined 101,921 Gizzard Shad <6 inches 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 194) over 100 miles downstream from the electric barrier system.
- Recommend continued monitoring for young Asian carp, and a new project to enhance understanding of young Asian carp distribution and habitat selection.

Distribution and Movement of Small Asian Carp in the Illinois Waterway (31) - This was 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.

- Results include a total of 72,015 fish specimens collected and examined. Eighty species and 3 hybrid combinations were identified. Nine species collected were non-native exotics.
- A total of four post-larval Silver Carp YOY specimens were identified from three mini-fyke net collections made during 4 to 6 June 2012. All three collections were made in the Peoria Pool, one in the vicinity of Henry, IL and two near Chillicothe, IL. Sizes of the specimens range from 16-21mm total length. No other YOY Asian carp were collected during this study.
- The collection of YOY silver carp suggests that at least limited reproduction occurred in the spring of 2012. The fact that only four specimens were collected suggests that Asian carp reproduction was not widespread or common in the river reaches we examined during 2012. The locations where the four specimens were collected represent the furthest upstream documentation of YOY silver carp in the IWW.
- Recommend continued monitoring for small Asian carp in the IWW.

Fixed Site Monitoring Downstream of the Dispersal Barrier (36) – This project included monthly standardized monitoring with pulsed-DC electrofishing gear and contracted commercial fishers at four fixed sites downstream of the electric barrier system 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 5,267 person-hours spent sampling at fixed sites and additional netting locations downstream of the electric barrier system from 2010-2012.
- 94.5 hours spent electrofishing and 81.1miles of trammel/gill net deployed.
- Sampled 60,709 fish, representing 84 species and four hybrid groups.
- No Bighead or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- A total of 25 Bighead Carp and no Silver Carp captured during contracted commercial netting at Dresden Island Pool fixed sites and additional netting locations.
- Detectable population front of mostly Bighead Carp located just north of I-55 Bridge at river mile 280 (47 miles from Lake Michigan). No appreciable change in upstream location of the population front in past five years.
- Sampled 17 Bighead Carp and 185 Silver Carp by electrofishing, and 455 Bighead Carp and 258 Silver Carp by netting at fixed sites and additional netting locations in Marseilles Pool. Presence of mature adults capable of spawning occurred in this pool about 55 miles from Lake Michigan. However, Asian carp larvae and juveniles were not detected upstream of Peoria Pool or less than 100 miles downstream of the electric barrier system and 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 start hoop and mini-fyke netting in June 2013. Also recommend shifting more sampling efforts from the CAWS to the Upper Illinois Waterway.

REMOVAL PROJECTS

Rapid Response Actions in the CAWS (46) – This project uses a threshold framework to support decisions for response actions to remove any Asian carp from the CAWS upstream of the electric barrier system with conventional gear or rotenone.

- Completed five response actions with conventional and experimental gears in the CAWS upstream of the electric barrier system during 2012. Three of the actions were triggered by three consecutive positive detections for Asian carp eDNA in the same location.
- Estimated 1,630 person-hours were spent to complete 59 hours of electrofishing, set 18.4 miles of trammel/gill net, make three 800-yard long commercial seine hauls, and deploy two tandem trap nets, 10 hoop nets and two Great Lake pound nets equal to 30.3 net-days of effort.
- Across all response actions and gears, sampled over 29,818 fish representing 53 species and 2 hybrid groups.
- No Bighead or Silver Carp were captured or observed during response actions.
- US Fish and Wildlife Service is maintaining a stored supply of rotenone and sodium permanganate to facilitate a rotenone response action (either in the CAWS or elsewhere in Great Lakes Basin) should conditions warrant such an action in the future.
- Recommend continued vigilance in removing any Bighead or Silver Carp from the CAWS upstream of Lockport Lock and Dam and development of a new threshold framework to guide decisions on rapid response actions in the CAWS. Also recommend establishing planned intensive surveillance at selected locations in the CAWS outside the threshold framework when information gained from such actions may benefit monitoring protocols, research efforts, or Asian carp removal and control efforts.

Barrier Maintenance Fish Suppression (52) – This project provides a fish suppression plan to support US Army Corps of Engineers maintenance operations at the electric barrier system. The plan includes fish sampling to detect juvenile or adult Asian carp presence in the Lockport Pool downstream of the electric barrier system, 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 at the electric barrier system for necessary barrier maintenance on 3 separate operations (May 12th, June 21st and November 14th)
- In 2012, a total of 100 fish were removed with 13 fish > 12 inches in length by hydroguns, surface and deep-water electrofishing and 30-foot deep gill netting.
- A total of 6 hours of split-beam hydroacoustics, side-scan SONAR, and DIDSON imaging SONAR where used to assess the success of the fish clearing operation by surveying the area in and near the electric barrier system.
- No Asian carp were captured or observed during fish suppression operations
- Recommend continued use of hydroacoustics to survey at the electric barrier system for fish > 12 inches and sample using surface and deep-water electrofishing alongside 30-foot deep gill nets to effectively remove all threats in the electric barrier system.

Barrier Defense Asian Carp Removal Project (56) – This program was established to reduce the numbers of Asian carp downstream of the electric barrier system 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 electric barrier system. Primary areas fished include Dresden Island, Marseilles, and Starved Rock pools.

- Contracted commercial fishers and assisting IDNR biologists deployed 643.3 miles of net in the upper Illinois Waterway from 2010-2012.
- A total of 44,658 Bighead Carp, 47,474 Silver Carp, and 496 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 698.72 tons (62.41 tons in 2010, 351.78 tons in 2011 and 284.53 tons in 2012).
- 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 barrier system and Lake Michigan.

Monitoring Asian Carp Population Metrics and Control Efforts: Preventing Upstream Movement in the Illinois River (64) - 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.

- Side-scan SONAR plus split-beam hydroacoustics were effective at evaluating the presence of fish > 12 inches in length in the electrical barrier canal system. This monitoring system was deployed nine times in 2012 as part of barrier maintenance fish suppression.
- In Marseilles Pool, 279 Bighead Carp and 34 Silver Carp were tagged externally (jaw tags). Forty-nine percent of these fish were recaptured in 2012.
- Retrieval of tagged Asian carp showed us that contracted harvest caused 79% mortality in the quarry adjacent to Marseilles Pool.
- Frequency of the decline of tagged fish relative to untagged fish showed that immigration into the quarry was significant.
- Telemetry and acoustics showed that Asian carp in the quarry frequently move into the main channel and back.
- In spring 2012, 3,000,000 pounds of Asian carp were removed from Peoria, LaGrange, and Alton pools of the lower Illinois River as part of a fishing experiment to aid population reduction model development.
- Sampling with electrofishing and trammel netting in late summer 2012 showed a decline in catch rates of Silver Carp by 33% in the lower river.
- Sex ratio of Asian carp shifted toward 17% more males than females.
- Analysis of age structure revealed that very little recruitment of Asian carp occurred in 2010 and perhaps 2011.

- Samples of fish putatively identified as “pure” Silver Carp, “pure” Bighead Carp, and hybrids have been sent to Western Illinois University for genetic analysis.
- Hydroacoustic surveys combining down-looking and side-looking transects were completed in the river, comprising 2,306 miles of data collection. Analysis is ongoing. Habitat covered included 82.6% main channel, 5.2% backwater lakes, 5.1 % contiguous lakes, 4.9% side channels, 1.5% tributaries, and 0.4% harbors.
- A network of 30 stationary acoustic receivers for detecting tagged fish is now in place in the Illinois River (not including those receivers maintained by other research groups). Receivers were also placed in all IWW lock chambers in early 2013.
- Three-hundred and seventy-two Asian carp were implanted with acoustic tags by fall 2012.
- Stationary receivers made about 250,000 detections of tagged Asian carp by fall 2012 and 157 Asian carp were located. At least 17 Asian carp with transmitters were removed by harvest.
- In the upper river, no upstream movement of Asian carp was detected. Movement within pools was frequent.
- Elemental composition of Asian carp otoliths provided an environmental history. Up to 40% of Silver Carp in the Illinois River were produced outside the river, likely in the Middle Mississippi River. Conversely, only 3% of Bighead Carp derived from outside the Illinois River.
- Recommend further refinement of the acoustic target strength (TS) to body size relationship for Asian carp to determine uncertainty in size estimates.
- Recommend multi-frequency TS evaluations of Asian carp and other fishes to examine whether multinomial probabilistic models can be used to determine species-specific information.
- Recommend evaluation of 70 kHz frequency transducers for appropriateness of use in future surveys.
- Recommend continuing mark/recapture monitoring with increase in number of tagged fish and improvements to recapture recording process
- Recommend continued standardized sampling to provide baseline information for the effects of commercial harvest on the Asian carp population in the Illinois River
- Recommend continued monitoring of Asian carp with acoustic transmitters and increased effort to locate tagged fish in side channel and backwater habitat.
- Recommend continued monitoring of natal origin of Asian carp to determine effects of commercial harvest on recruitment sources.

BARRIER EFFECTIVENESS EVALUATIONS

Telemetry Monitoring Plan (69) – This project uses ultrasonically tagged 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, 5.5 million detections have been acquired from 238 tagged fish
- Our preliminary conclusion from the small fish and adult fish telemetry studies is that the barriers are effectively preventing all upstream passage of tagged fish. (surrogate species for Asian carp are used where Asian carp are not present)
- We have observed inter-pool movement of tagged Common carp at all locks within the study area and one Bighead Carp at the Dresden Island Lock.
- Based on the few Asian carp tagged in Dresden Island Pool, our preliminary conclusion is that the leading edge of adult Asian carp in Dresden Island Pool has not changed but individual fish do scout ahead of the main front as far north as the Brandon Road Lock and Dam.
- Recommend 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.

Evaluation of Fish Behavior at the Dispersal Barrier (77) – This project uses Dual-Frequency Identification SONAR (DIDSON) and caged fish experiments to monitor fish behavior at the barrier. Caged fish experiments will describe behavior of various-sized fish (not Asian carp) subjected to the electric barrier system's electric field and DIDSON surveys will determine relative abundance of fish upstream, in, near, and downstream of the electric barrier system.

- Increased fish abundances were documented below the electric barrier system in the summer and fall, small fish were recorded immediately below the highest electrical field.
- All caged fish that were moved through Barrier IIA or IIB after operating parameters were increased to 2.3 V/in were incapacitated; however, eight Common Carp were not incapacitated and two Freshwater Drum that were moved through the Demonstration Barrier did not show avoidance behavior.
- Two weeks of intensive caged-fish work involving barges were performed and plans for future evaluations of barge-fish interactions are underway.
- Recommend continued DIDSON monitoring at the electrical dispersal barrier system with addition of hydroacoustic SONAR scans monthly around barrier maintenance events
- Recommend developing hydroacoustic experiment to test ability to identify Asian carp to species.

Des Plaines River and Overflow Monitoring (83) – 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.

- Captured 3,175 fish representing 44 species from 13 families and two hybrid groups during 12.6 hours of electrofishing and 21 net sets on the upper Des Plaines River.
- No Asian carp were captured or observed.
- Recommend continued monitoring for the presence of Asian carp adults and/or juveniles at three sites in the upper Des Plaines River and continued investigations in the area of overtopping events. Removal of the Hofmann Dam in 2012 has created opportunity for fish to advance further up the Des Plaines River; therefore it is recommended that monitoring also extend further upstream in 2013.

GEAR EFFECTIVENESS EVALUATIONS AND DEVELOPMENT PROJECTS

Asian Carp Gear Efficiency and Detection Probability Study (87) – 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 Asian 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.

- Asian carp relative abundance was highest in the LaGrange and Peoria Pools; no Asian carp were caught upstream of Morris (Marseilles Pool), and none were caught in the CAWS.
- Possible age-1 Asian carp (<500 mm) were relatively abundant in the LaGrange and Peoria Pools, but only one was caught in the Starved Rock Pool, and none in the Marseilles Pool. Only one age-0 Asian carp (<300 mm) was captured (at Peoria Lock & Dam, LaGrange Pool).
- Electrofishing was the most effective gear for sampling Silver Carp and hybrid Asian carp, while hybrids were also captured in hoop nets. Hoop nets, trammel nets, and fyke nets were the most effective gears for capturing Bighead Carp.
- Recommend further sampling to refine optimal sampling protocols and determine annual trends in Asian carp abundance. Because 2012 represented another poor recruitment year for Asian carp, sampling during high recruitment years will be required to determine sampling efficacy for age-0 Asian carp across gears.

Exploratory Gear Development Project (92) – A professional net designer has been consulted to develop and build enhanced purse seines, trawls, and gill nets for more effective harvest of Asian carp. Enhanced gears will be evaluated in areas known to have abundant Asian carp populations.

If effective, gears may be used in place of rotenone for removal actions in the CAWS and for commercial fishing in the lower Illinois River or other Asian carp infested waterways.

Purse Seine:

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

Paupier (Butterfly net):

- The paupier captures juvenile Asian carp and could be used for this purpose
- Adult Asian carp were not readily captured and there may only be a specific temperature or habitat for which the gear is effective
- Appears to be a valuable tool for sampling juvenile Paddlefish

Unconventional Gear Development Project (96) –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.

- No Asian carp were captured in the Great Lakes trap net in Lake Calumet over 107 net-days. The Great Lakes trap nets were effective at capturing Asian carp in the Material Services pit (Marseilles Pool) over 70 net-days (705 Asian carp - 512 Bighead Carp, 85 Silver Carp, 108 Bighead x Silver Carp hybrids).
- Surface-to-bottom gill nets caught more Asian carp than traditional gill nets per 4-hour set, whereas surface-to-bottom gill nets had similar catch rates to large mesh sinking gill nets per unit area of net.
- Standard small (1.2 m diameter) hoop nets caught more Asian carp than large (2 m) hoop nets per net night.
- Spreading soybean meal on the surface of the water did not increase catches by attracting Asian carp to feed.
- Recommend further sampling to refine optimal sampling protocols and efficacies, the Great Lakes trap nets represent a possible tool for long-term monitoring in standing or low-flow areas, but may represent targets for vandalism and may not be appropriate for setting in flowing water.

Water Gun Development and Testing (100) – 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 barrier system maintenance.

- Behavioral responses of Silver Carp were characterized under controlled conditions.
- Pressure gradients around the 120-in^3 water gun were mapped.
- Investigations of the response of Silver Carp to pure and complex tones, including those of outboard motors, were initiated through collaboration with the University of Minnesota-Duluth.
- Recommend the continued use of water guns to clear fish at the electric barrier system in support of barrier maintenance operations and additional testing of this technique as a deterrent and control strategy for invasive species management.

ALTERNATIVE PATHWAY SURVEILLANCE

Alternate Pathway Surveillance in Illinois (Law Enforcement 108, Urban Ponds 111) – This project creates a more robust and effective enforcement component of IDNR's invasive species program by increasing education and enforcement activities at bait shops, bait and sport fish production/distribution facilities, fish processors, and fish markets/food establishments known to have a preference for live fish for release or food preparation. A second component conducts surveys at urban fishing ponds in the Chicago Metropolitan area included in the IDNR Urban Fishing Program as well as ponds with positive detections for Asian carp eDNA using conventional gears (electrofishing and trammel/gill nets) in an effort to remove potential accidentally stocked Bighead or Silver Carp.

Law Enforcement:

- Invasive species unit (ISU) in IDNR law enforcement was formed.
- ISU logged 1,035 hours investigating invasive species issues.
- ISU gained much intelligence from a Chicago area live fish market inspection.
- Conducted a joint investigation with USFWS in which several charges and penalties were given to an out-of-state fish hauler.
- A multi-agency Asian carp task force was formed to share intelligence, information and plan future operations.
- Recommend increased surveillance of fish haulers stocking local water bodies, area fish production facilities, and especially live fish markets with continued surveillance of the bait trade in the Chicago metropolitan area.

Urban Fishing Pond Surveys:

- Sampled 19 ponds with electrofishing and trammel/gill nets during 2012.
- Estimated 727 person-hours were spent to complete 30 hours of electrofishing and set 6.2 miles of trammel/gill net.
- Sampled 9,103 fish representing 29 species and 2 hybrid groups.
- Six Bighead Carp were removed from three ponds (Garfield Park, Humboldt Park, Joe's Pond); three are on exhibit at the John G. Shedd Aquarium.
- Recommend additional sampling of ponds from which Bighead Carp were removed, as well as repeat sampling of ponds yielding positive results for Asian carp eDNA.

2012 Monitoring and Rapid Response Plan Interim Summary Reports

May 2013

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). The MRRWG 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 MRRWG was assigned the task of developing and implementing a Monitoring and Rapid Response Plan (MRRP) for Asian carp that were present or could gain access to the Chicago Area Waterway System (CAWS).

The latest version of the MRRP was released in May 2012. It included 18 individual project plans 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 2011). This plan was used to guide and coordinate 2012 action agency efforts to accomplish strategic objectives and achieve the specific goal of preventing Asian carp from establishing populations in the CAWS and Lake Michigan. Projects were classified geographically as occurring either upstream or downstream of the Dispersal Barrier in Romeoville, Illinois and grouped into five categories: Monitoring Projects, Removal Projects, Barrier Effectiveness Evaluations, Gear Effectiveness Evaluations and Development Projects, and Alternative Pathway Surveillance (MRRWG 2012).

The workgroup has adopted an adaptive management approach to Asian carp monitoring and removal and considers the MRRP to be a working document that is continually open to modification and enhancement. To foster an adaptive management approach, the 2012 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 MRRP for the coming year.

This document is a compilation of summary reports covering each of the 18 project plans included in the 2012 MRRP. It should be viewed as a companion document to the updated 2012 MRRP. Reports include summaries of activities completed during the 2012 or, for some projects, 2010 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 2013 plan. Most are interim reports with data summaries, analyses, and interpretations that are preliminary in nature but still offer a scientific basis for 2012 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 Site Monitoring Upstream of the Dispersal Barrier

John Zeigler, Tristan Widloe, Blake Ruebush, Michael McClelland, David Wyffels, Brennan Caputo, Matthew O'Hara, Victor Santucci
and Kevin Irons; 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 barrier system 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 barrier system. Reach electrofishing sampling (performed in 2010 and 2011) was replaced with random area electrofishing and netting in 2012. Sampling results from 2010 – 2012 contributed to our understanding of Asian carp population abundance in the CAWS providing guidance for conventional gear or rotenone rapid response actions designed to remove fish from areas where they have been captured or observed.

Objectives: **S**tandardized 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 barrier system;
2) Determine relative abundance of Asian carp 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 site sampling areas. Sampling took place monthly during March through December and twice monthly from April through November. Stations were located in areas where the likelihood of Asian carp capture is the greatest (i.e. where eDNA has been detected, below migration barriers, or both) 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. The five fixed sites are mostly 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 barrier system would 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. See Fixed and Random Site Monitoring Upstream of the Dispersal Barrier in the 2012 Monitoring and Rapid Response Plan (MRRP) for a description of fixed sites and effort for each site.

The entire CAWS upstream of the electric barrier system was divided into four random sampling areas that were sampled three times per month with pulsed-DC electrofishing gear and 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 twice monthly as part of 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. See Fixed and Random Site Monitoring Upstream of the Dispersal Barrier in the 2012 MRRP for a description of random areas and effort for each area. Fixed and random site sampling provided intense sampling in areas thought to be the most likely places to catch Asian carp if they are in the waterway, and somewhat less intense, broad coverage of the entire CAWS.

Electrofishing Protocol – All electrofishing used pulsed-DC current and included 1-2 netters. Locations for each electrofishing transect for 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 counted to provide an assessment of young Asian carp in the waterway.

Netting Protocol – Contracted commercial fishers were used for net sampling at the fixed and random sites. The nets used were large mesh (3.0-4.0 inches) trammel or gill nets 8-10 feet high, and in lengths of 100 or 200 yards. Most sets were 200 yards long, although some sets were longer (up to 600 yards) due to low water restricting access to fixed site locations. Random site coordinates were randomly generated as described above. Net sets took place within 500 yards 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 150 yards from the net. Captured fish were identified to species and recorded on data sheets.

Results and Discussion: Crews logged over 9,600 person-hours of effort while electrofishing and netting fixed sites upstream of the electric barrier system during 2010 – 2012. Over three years, approximately 475 hours of electrofishing was completed and 139 miles of trammel/gill net was deployed. In 2012, a total of 99,234 fish representing 63 species (plus hybrid sunfish and Common Carp x Goldfish hybrids) were collected in 192 hours of electrofishing and 81.7 miles of net during fixed and random site sampling (Table 1). Fixed site sampling in 2012 accounted for 3,713 person-hours, 135 hours of electrofishing, and 55.2 miles of trammel/gill netting. Random site sampling in 2012 accounted for an additional 3,805 person-hours, 57 hours of electrofishing and 26.5 miles of trammel/gill netting (Table 1). Monitoring efforts were high in the CAWS compared to other river monitoring programs. For example, there were 135 hours spent electrofishing in fixed sites and 57 hours in random areas in the CAWS during 2012 vs. about 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 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 are the first examples of such reductions in effort.

Fixed Site Electrofishing – A total of 73,596 fish representing 60 species (plus hybrid sunfish and Common Carp x Goldfish hybrids) were sampled in 135 hours (537 transects) of electrofishing at fixed sites in 2012 (Table 1). This is an increase from 33,689 fish (51 species, plus hybrid sunfish and Common Carp x Goldfish hybrids) in 130 hours (519 transects) in 2010 and 52,339 fish (58 species, plus hybrid sunfish and Common Carp x Goldfish hybrids) in 211 hours (844 transects) in 2011. Fixed Site 2 (Little Calumet River) had the highest total catch (22,178 fish), species richness (47 species), and catch per unit effort (CPUE; 616 fish/hour) among fixed sites in 2012 (Table 2). The CPUE for all fixed sites combined increased from 259 fish/hour in 2010 and 248 fish/hour in 2011 to 547 fish/hour in 2012 (Table 1). Eight fish species comprised just over 90% of the total abundance of fixed site electrofishing samples in

2012. Gizzard Shad was the most abundant species, followed by Bluegill, Bluntnose Minnow, Pumpkinseed, Golden Shiner, Largemouth Bass, Common Carp, and Emerald Shiner. Gizzard Shad was the most abundant species across all three years of fixed site electrofishing, comprising 41-55% of the total catch per year. No Bighead or Silver Carp have been captured or observed to date during fixed site electrofishing in the CAWS. In addition, we examined a total of 27,042 Gizzard Shad < 6 inches from fixed sites in 2012 and detected no Asian carp YOY.

Random Area Electrofishing – In 2012 reach monitoring upstream of the 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 22,623 fish representing 51 species (plus hybrid sunfish and Common Carp x Goldfish hybrids) were sampled during 57 hours of electrofishing (228 transects) at random areas in 2012 (Table 1). Random Area 2 (Little Calumet River/Cal-Sag Channel) had the greatest total catch (6,934 fish) and CPUE (533 fish/hour) and Random Area 1 (Calumet Connecting Channel/ Calumet River) had the highest total species richness (35 species) among random areas in 2012 (Table 2). Reach site electrofishing produced a total of 2,734 fish of 33 species (plus hybrid sunfish and Common Carp x Goldfish hybrids) during 78 hours (244 transects) in 2010 and a total of 2,383 fish of 35 species (plus hybrid sunfish) during 88 hours (348 transects) in 2011. Though 120 fewer electrofishing transects were performed at random sites in 2012, 20,240 more fish were collected than at reach sites in 2011. The CPUE for all random sites combined was 397 fish/hour in 2012, and 35 and 27 fish/hour during reach sampling in 2010 and 2011, respectively. Ten fish species comprised over 90% of the total abundance of random area electrofishing samples in 2012. Gizzard Shad was the most abundant species, followed by Common Carp, Bluntnose Minnow, Mosquitofish, Bluegill, Brook Silverside, Emerald Shiner, Largemouth Bass, Pumpkinseed, and Golden Shiner. As with fixed site electrofishing, Gizzard Shad was the most abundant species in the 2012 random sampling as well as the 2010 and 2011 reach sampling, comprising 41-56% of the total catches per year. No Bighead or Silver Carp were captured or observed during random site electrofishing in the CAWS. In addition, crews examined a total of 9,637 Gizzard Shad < 6 inches from random sites in 2012 and detected no Asian carp YOY.

Fixed Site Netting – A total of 1,856 fish representing 20 species (plus Common Carp x Goldfish hybrids) were sampled in 55.2 miles of net (467 sets) at fixed sites in 2012 (Table 1). This was a decrease from 2,439 fish (17 species, plus Common Carp x Goldfish hybrids) in 23.8 miles of net (208 sets) in 2010 and 5,062 fish (19 species, plus Common Carp x Goldfish hybrids) in 60.4 miles of net (352 sets) in 2011. Fixed Site 1 (Lake Calumet) had the highest total catch (1,041 fish), CPUE (2.9 fish/100 yards of net), and species richness (16 species) among fixed sites in 2012 (Table 3). CPUE for all fixed sites combined decreased from 5.8 fish/100 yards of net in 2010 and 4.8 fish/100 yards of net in 2011, to 1.9 fish/100 yards of net in 2012 (Table 1). The five most common fish species captured in 2012, which comprised over 95% of the total abundance of fixed site netting samples in 2012, were Common Carp, Freshwater Drum, Smallmouth Buffalo, Black Buffalo, and Quillback. Common Carp were the most abundant species across all three years of fixed site netting, comprising 50-76% of total catches per year. No Bighead or Silver Carp were observed or collected in fixed site net sampling upstream of the electric barrier system in 2012.

Random Area Netting – In addition to random area electrofishing, random area netting also began in 2012. A total of 1,159 fish representing 7 species (plus Common Carp x Goldfish hybrids) were collected in 26.5 miles of net (232 sets; Table 1). While the CPUE for all random areas combined was low (2.5 fish/100 yards of net) it was still higher than that of the fixed sites in 2012 (1.9 fish/100 yards of net; Table 1). Random Area 3 (Chicago River/South Branch/CSSC) had the greatest total catch (625 fish) and CPUE (3.9 fish/hour) among random areas in 2012 (Table 3). Species richness was even across random areas with 4 species total at each area except random area 3 that had five species total (Table 3). The five most common fish species/hybrid groups were Common Carp, Common Carp x Goldfish hybrid, Freshwater Drum, Goldfish, and Smallmouth Buffalo. Combined, these species comprised 99.7% of the total abundance of species collected in random area netting in 2012. No Bighead or Silver Carp were captured or observed during random area netting in the CAWS in 2012.

Recommendations: As a result of the extensive sampling with conventional gears to this date, we conclude that if there are any live Bighead Carp or Silver Carp in the CAWS upstream of the electric barrier system, 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 2013 sampling season. The number of fixed sites and random areas, and the number of transects at each site/area, for each sampling event, will remain the same as in 2012. However, the frequency of fixed site electrofishing sampling events will be reduced from twice monthly (April-November) to once monthly for the entire sampling season. The frequency of random area electrofishing will be reduced from three times monthly to twice monthly. This reduction in effort upstream of the electric barrier system would provide an opportunity to increase sampling downstream of the Dispersal Barrier (See Fixed Site Monitoring Downstream of the Dispersal Barrier, below). The increase in sampling downstream of the electric barrier system 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 barrier system 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 barrier system.

Project Highlights:

- Estimated over 9,600 person-hours spent sampling at fixed sites upstream of the electric barrier system in 2010, 2011 and 2012.
- Estimated 3,713 person-hours spent sampling at fixed sites, and 3,805 person-hours spent sampling in random areas upstream of the electric barrier system in 2012
- 533 hours spent electrofishing and 165.9 miles of trammel/gill net deployed at fixed sites in 2010, 2011, and 2012 and random areas in 2012.
- 192 hours spent electrofishing and 81.7 miles of trammel/gill net deployed at fixed sites and random areas in 2012.
- Sampled 192,763 fish representing 67 species and two hybrid groups during electrofishing and trammel/gill netting at fixed sites in 2010, 2011, and 2012 and random sites in 2012.

- Sampled 99,234 fish representing 63 species and two hybrid groups in during fixed and random electrofishing and trammel/gill netting 2012.
- No Bighead or Silver Carp captured or observed during fixed site and random area electrofishing and netting in 2012.
- Based on the extensive sampling performed upstream of the electric barrier system, and the need for more sampling downstream of the electric barrier system, we recommend reducing the frequency of electrofishing at fixed sites and random areas upstream of the electric barrier system and increasing sampling downstream of the electric barrier system.

Table 1. Electrofishing and netting efforts and catch summaries for 2012 fixed site and random area sampling upstream of the electric barrier system.

	Fixed Sites	Random Areas	
Electrofishing Effort	2012 (Mar-Dec)	2012 (Mar-Dec)	Total
Person-days	204	229	433
Estimated person-hours	2,040	2,290	4330
Electrofishing hours	135	57	192
Samples (Transects)	537	228	765
Electrofishing Catch			
All Fish (N)	73,596	22,623	96,219
Species (N)	60	51	62
Hybrids (N)	2	2	2
Bighead Carp (N)	0	0	0
Silver Carp (N)	0	0	0
CPUE (fish/hr)	547	397	501
	Fixed Sites	Random Areas	
Netting Effort	2012 (Mar-Dec)	2012 (Mar-Dec)	Total
Person-days	223	202	425
Estimated person-hours	1,673	1,515	3,188
Samples (net sets)	467	232	699
Total miles of net	55.2	26.5	81.7
Netting Catch			
All Fish (N)	1,856	1,159	3,015
Species (N)	20	7	25
Hybrids (N)	1	1	1
Bighead Carp (N)	0	0	0
Silver Carp (N)	0	0	0
CPUE (fish/100 yards of net)	1.9	2.5	2.1

Table 2. Numbers of fish sampled with pulsed-DC electrofishing in fixed sites and random areas of the CAWS upstream of the electric barrier system in 2012. (*) 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	7,747	12,465	10,277	5,833	4,265	1,219	4,962	3,195	3,245	53,208
Bluegill	960	992	1,147	1,138	1,936	103	62	337	249	6,924
Bluntnose Minnow	1,396	1,444	366	149	1,488	308	244	508	138	6,041
Common Carp*	611	1,064	559	332	353	65	1,171	641	450	5,246
Pumpkinseed	833	1,963	429	81	315	156	10	202	69	4,058
Golden Shiner	1,367	91	1,210	293	579	19	24	26	340	3,949
Largemouth Bass	1,051	1,226	302	148	581	290	44	9	110	3,761
Emerald Shiner	553	433	346	80	47	395	68	85	12	2,019
Brook Silverside	444	681	42			599	9		35	1,810
Mosquitofish		1	358	2	5		1	1,174		1,541
Spotfin Shiner	22	324	583	240	94	37	27	148	58	1,533
Green Sunfish	31	430	238	71	122	31	163	108	25	1,219
White Sucker	8	53		328	162	19	1	2	73	646
Banded Killifish	70	285				44	9		1	409
Smallmouth Bass	62	1	3		9	221	1	61	5	363
Yellow Perch	156	7	2	25	17	106			1	314
Yellow Bullhead	17	111	49	37	5		15	45	22	301
Spottail Shiner	79	17	2	15	15	12		95	9	244
Goldfish	66	93	14	13	14	9	6	10	6	231
Alewife	26	2	4	6	106	56			21	221
Round Goby	120	20			2	64	2			208
Freshwater Drum	93	14	3			47	11	1		169
White Perch	80	34	4	3	19	9	4	1	9	163
Blackstripe Topminnow				53	95				2	150
Rock Bass	10	6	1	3	20	106	1			147
Black Bullhead	22	46	16	12	3		2	27	9	137
Hybrid Sunfish	13	19	63	9	8	5			3	120
Orangespotted Sunfish	27	78		2	3					110
Channel Catfish	47	7	9	7	3		18	9	2	102
Threadfin Shad	1	69	8				3		11	92
Oriental Weatherfish		9	52	5	8			4	13	91
White Bass	67	9				10	1			87
Brown Bullhead	2	38	9	1	2		1	20	2	75
Creek Chub		4	1		3		60	2		70
Bullhead Minnow	1	46					3	1		51
Chinook Salmon	16	4		1	4	15				40
Fathead Minnow	2	11	1		11	13	1	1		40
Black Crappie	1	1	5	3	17		1		10	38
River Carpsucker						33				33
Quillback	18			3		10				31
Black Buffalo	7	21				1				29
Smallmouth Buffalo	18	4				6				28
Bigmouth Buffalo	16					9			1	26
Unidentified Ictalurid		26								26
White Crappie	3	10	1	4	2					20
Yellow Bass		1	2	1	9		2	2		17

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
Rainbow Trout	1		1			10			3	15
Common Carp x Goldfish hybrid		2	2		6	2				12
Warmouth		3		1	1	3			2	10
Central Mudminnow		5					4			9
Grass Carp	1					1	3			5
Bowfin		3							1	4
Coho Salmon					1				2	3
Ghost Shiner					3					3
Sand Shiner					3					3
Walleye			2						1	3
Brown Trout					1	1				2
Grass Pickerel		1		1						2
Silver Chub		2								2
Unidentified Salmonid	2									2
Common Shiner		1								1
Flathead Catfish	1									1
Mottled Sculpin		1								1
Northern Pike						1				1
Redear Sunfish			1							1
Threespine Stickleback	1									1
Total Caught	16,069	22,178	16,112	8,900	10,337	4,035	6,934	6,714	4,940	96,219
Species	43	47	34	32	38	35	33	26	33	62
Hybrid Groups	1	2	2	1	2	2	0	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 barrier system in 2012.

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	556	445	249	24	34	22	120	596	364	2,410
Freshwater Drum	334	16	3			3	2	6	3	367
Smallmouth Buffalo	46	3	1		1	2	2	2		57
Common Carp x Goldfish hybrid	1	6	5	3	1		1	15	10	42
Black Buffalo	25	2				1				28
Quillback	24									24
Goldfish	1	3	5	3	1			5	2	20
Channel Catfish	13	1		1				1	1	17
Gizzard Shad	15	1								16
Bigmouth Buffalo	9	2					1			12
Flathead Catfish	4									4
River Carpsucker	4									4
Chinook Salmon	3									3
Largemouth Bass	1	1								2
Smallmouth Bass	2									2
Grass Carp	2									2
Bluegill				1						1
White Sucker				1						1
Black Bullhead			1							1
White Bass	1									1
Rainbow Trout		1								1
Total Caught	1,041	481	264	33	37	28	126	625	380	3,015
Species	16	10	5	5	3	4	4	5	4	20
Hybrid Groups	1	1	1	1	1	0	1	1	1	1

Strategy for eDNA Monitoring in the CAWS

Kelly Baerwaldt; US Army Corps of Engineers – Rock Island District
Shawna Herleth-King; US Army Corps of Engineers – Chicago District

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

Introduction: In 2009 the University of Notre Dame (UND), through a cooperative agreement with the USACE, developed a monitoring tool that could detect "environmental" DNA (left behind in mucus, feces, urine, etc.) from Asian carp (i.e. *Hypophthalmichthys nobilis* and *H. molitrix)* in the aquatic environment. The method was primarily employed in areas where traditional fishery techniques (e.g. electrofishing and netting) were thought to be ineffective and in areas where Asian carp were thought to be either absent or present in low densities. At present, the detection of eDNA evidence cannot discern the source of the DNA 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. In addition, a positive detection does not reveal how Asian carp DNA came to be present at a particular location. Monitoring for the presence of eDNA above the electric dispersal barrier system has occurred since 2009. The results of eDNA sampling in conjunction with traditional fishery techniques has guided Rapid Response actions designed to remove Asian carp from the waterway. In addition, results of eDNA have been used to inform decisions regarding the success of removal efforts and when individual actions should be terminated.

Objectives: eDNA sampling was conducted during the 2012 field season to:

1) Determine whether Asian carp DNA is present in strategic locations in the Chicago Area Waterway System (CAWS) to help guide Rapid Response actions; and
2) Detect Asian carp DNA in areas targeted for Rapid Response actions, as a measure of the effectiveness of conventional gear or rotenone removal efforts

Methods: In general, IDNR and USFWS collected 120 water samples on a bi-weekly basis from a specified reach of the CAWS on either a Monday or Tuesday. Samples were then transferred to USACE biologists at the USEPA Chicago Regional Laboratory where they were filtered and preserved in a -20°C freezer. Preserved samples were then shipped overnight to the Engineering and Research Development Center (ERDC) laboratory for analysis. Results were posted on the USACE-Chicago District web site (http://www.lrc.usace.army.mil/Missions/CivilWorksProjects/ANSPortal/eDNA.aspx) after analysis of each sampling event was completed (approximately 14 days). Detailed field, laboratory, and reporting protocols are available in the eDNA Quality Assurance Project Plan (USACE 2011).

Locations – Samples were collected bi-weekly from May through October (weather permitting) such that Lake Calumet and each partial barrier to Lake Michigan were sampled once each month (N=114 samples and 6 cooler blanks bi-weekly). Sample locations were selected based on habitat thought to be preferred by Asian carp (i.e. Lake Calumet) and entry points to Lake Michigan (i.e. North Shore Channel downstream from Wilmette Pumping Station, Chicago River downstream from Chicago Lock, and Little Calumet River downstream from T.J. O'Brien Lock and Dam). Sampling was complementary to fixed site sampling conducted with conventional gears in the locations listed below.

- North Shore Channel (W 41.9740º, N 87.7044º) - 60 samples and South Branch Chicago River to the Chicago Lock (W 41.8892º, N 87.6085º) - 60 samples
- Little Calumet River downstream of T.J. O'Brien Lock (W 41.6786º, N 87.5783º) - 60 samples and Lake Calumet (W 41.6529º, N 87.5679º) - 60 samples

The following environmental variables were collected during sampling events: temperature (ºC), channel depth (m), dissolved oxygen concentration (mg/L), conductivity (µS/cm), and pH. Due to equipment limits or equipment failure, data was not collected for each sample. Environmental variables were assessed between samples testing positive for either silver carp or bighead carp DNA and samples testing negative for Asian carp DNA. An F-test was conducted prior to a t-test to determine if samples variances differed significantly. Depending on the result, either a two-sample t-test assuming equal variances or a two-sample t-test assuming unequal variances was conducted to compare environmental variables between the two sample groups.

Results: A total of 1,196 water samples along with 64 control samples were collected and analyzed from reaches upstream of the electric dispersal barrier system. One-hundred fifty-three (153) samples were positive for Silver Carp DNA and four (4) samples were positive for Bighead Carp DNA (Table 1). In addition, 14 water samples and 1 control sample were collected from the International Harborside Golf Course lake, which does not overflow into the CAWS but is adjacent to the northern portion of Lake Calumet. One (1) sample was positive for Silver Carp DNA while zero (0) samples were positive for Bighead Carp DNA. During the 2012 season, an estimated 428 person-hours were spent in the collection of samples and filtering of 2,420 liters of water collected above the electric barrier system (Table 2).

Silver Carp

A two-sample t-test assuming equal variances was conducted to compare temperature, channel depth, dissolved oxygen concentration, and pH for samples testing positive for Silver Carp DNA and samples testing negative for Asian carp DNA. There was a statistically significant difference for temperature [$t(190) = 5.88$, $p < 0.000$], dissolved oxygen concentration [$t(184) = 6.05$, $p < 0.000$], and pH [$t(135) = 3.22$, $p < 0.001$] between samples positive for Silver Carp DNA and samples negative for Asian carp DNA. Channel depth [$t(190) = -1.81$, $p = 0.072$] did not differ significantly between the two groups. A two-sample t-test assuming unequal variances was conducted to compare conductivity for samples testing positive for Silver Carp DNA and samples testing negative for Asian carp DNA. Conductivity [$t(194) = 1.64$, $p = 0.102$] did not differ significantly between the two groups. For Silver Carp descriptive statistics refer to Table 3.

Bighead Carp
A two-sample t-test assuming unequal variances was conducted to compare temperature, channel depth, dissolved oxygen concentration, and conductivity for samples testing positive for Bighead Carp DNA and samples testing negative for Asian carp DNA. There was a statistically significant difference for temperature [$t(39) = 62.19$, $p < 0.000$], dissolved oxygen concentration [$t(25) = 55.18$, $p < 0.000$], and conductivity [$t(362) = 36.17$, $p < 0.000$] between samples positive for Bighead Carp DNA and samples negative for Asian carp DNA. Channel depth [$t(3) = 0.29$, $p = 0.789$] did not differ significantly between the two groups. A t-test was not conducted for pH since pH was not recorded for the four samples that tested positive for Bighead Carp DNA. For Bighead Carp descriptive statistics refer to Table 4.

Discussion: Although eDNA is a relatively new monitoring method, it has been validated by an independent external peer review (Blume et al. 2010) as an early detection monitoring tool for Bighead and Silver Carp DNA and was used in the Monitoring and Rapid Response Plan (MRRP) as a trigger for rapid response actions during the 2012 field season. The presence 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, or piscivorous birds. 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. Additionally, it is unknown how or if the number of positive samples correlates to the strength of the DNA source. The USACE is leading an interagency eDNA Calibration Study (ECALS) (http://www.asiancarp.us/ecals.htm) with USGS and USFWS to reduce the uncertainty surrounding eDNA results. The objectives of ECALS are to investigate eDNA vectors (alternative viable sources and pathways for DNA), develop more efficient markers to reduce sample processing time, determine broad estimates of population abundance; determine the effect of environmental variables on eDNA; and model eDNA transport in the CAWS.

Determine whether AC DNA is accumulating in strategic locations in the CAWS to help guide Rapid Response actions
During the 2012 field season, Asian carp DNA was found to be accumulating primarily within Lake Calumet (n=81; 51.6%) and the North Shore Channel (n=33; 20%). Consecutive sampling events with positive detections for Asian carp DNA triggered two rapid response actions in Lake Calumet, July 11-13 and October 30-31, and one rapid response action in the North Shore Channel, October 16-17. Prime aquatic habitat within Lake Calumet and the North Shore Channel could potentially explain the accumulation of DNA within these reaches, but only if eDNA results are indicative of a live Asian carp and not an alternative source. Both reaches are highly productive with Lake Calumet containing deep draft pools, shallow backwaters and side channels, gravel bars, and submergent and emergent aquatic vegetation, and the North Shore Channel containing shallow water habitat with submergent and emergent aquatic vegetation. However, the accumulation of Asian carp DNA within Lake Calumet and the North Shore Channel may be attributed to something other than the presence of a live fish. One explanation could be the existence of piscivorous avian species (e.g. cormorants, white pelicans, etc.) that inhabit both reaches. These birds could be consuming live Asian carp downstream in the Upper Illinois Waterway and then transferring the Asian carp DNA upstream through their excrement (Oehm et al. 2011). A second possibility for the accumulation of Asian carp DNA within Lake

Calumet and the North Shore Channel is the use of commercial nets during routine monitoring. As part of traditional routine monitoring, commercial fishermen use nets to sample for Asian carp both downstream and upstream of the electric barrier system. The same netting equipment that is used below the electric barrier system in reaches where Asian carp are abundant is used, without prior decontamination, in reaches above the electric barrier system. Although netting typically follows eDNA sampling within a reach, on a few occasions netting has occurred prior to eDNA sampling due to crew availability or weather. Without decontamination, these nets could be transferring Asian carp DNA to reaches above the electric barrier system where it could be remaining viable for several weeks. The viability of eDNA within the system is currently being determined by the ECALS. Other potential sources of eDNA accumulation include vectors such as boats, sediment and sewer outfalls. All of these vectors are being evaluated as part of the ECALS.

Detect AC DNA in areas targeted for Rapid Response actions, as a measure of the effectiveness of conventional gear or rotenone removal efforts

For the first time in three years, eDNA samples collected prior to rapid response actions returned positive detections for Asian carp DNA, even though intensive fish and netting efforts during the actions resulted in no Asian carp observed or captured. The initial rapid response occurred in Lake Calumet in June 2012. Sixty samples were collected from the lake prior to the event. Results indicated three positive detections for Silver Carp DNA, even though traditional fishery techniques resulted in no Asian carp being observed or captured during the two day event. The second rapid response of the 2012 field season also occurred in Lake Calumet in July. Forty-five eDNA samples were collected from the lake prior to the event. Results indicated two positive detections for Silver Carp DNA and again no Asian carp were observed or captured during the two day rapid response event. A third rapid response was conducted in the North Shore Channel in October 2012. Sixty eDNA samples were collected prior to the rapid response and analyzed for the presence of Asian carp DNA. Similar to the previous two rapid response eDNA sampling events, there were eight positive detections for Silver Carp DNA and no Asian carp were captured or observed during the two day rapid response action. A fourth rapid response was also conducted in Lake Calumet in October 2012. No eDNA samples were collected prior to the rapid response. No Asian carp were captured or observed over the course of the two day event.

The source or sources of the DNA for these positive detections is currently unknown. Alternative explanations for the positive detections, other than a live fish, could be the presence of DNA in channel sediments, bird excrement, and/or commercial netting used in the waterways. Further calibration of the eDNA method needs to be completed before the source of these positive detections can be understood.

Laboratory quality assurance/quality control

During the 2012 season there were two instances of sample contamination which resulted in the removal of effected sample results. The first incident occurred from samples collected on 2 October 2012. During analysis it was found that the cooler control was contaminated; therefore, all samples from that cooler were removed from further analysis. The second incident occurred from samples collected on 22 October 2012. During analysis it was found that the control for a single sample was contaminated which resulted in the sample being removed from further analysis.

Project Highlights:

- 2012 bi-weekly eDNA monitoring collected 1,196 samples from May through October, in addition to 14 samples collected from the International Harborside Golf Course lake.
- 153 samples from upstream of the electric dispersal barrier system were sequenced as positive for Silver Carp DNA and 4 samples were sequenced as positive for Bighead Carp DNA.
- An estimated 428 person-hours were spent collecting and filtering 2,420 liters of water in 2012.
- Consecutive eDNA positives triggered two Level I Rapid Response actions in Lake Calumet during July and October 2012 and one Level I Rapid Response action in the North Shore Channel during October 2012. No Asian carp were sampled or observed during conventional gear sampling. All eDNA samples collected immediately before the events returned positive DNA detections for silver carp.
- Recommend discontinuing eDNA as a trigger for Rapid Response Actions until further refinement of the technique is accomplished. Sampling events above the electric barrier system should occur on two snapshot occasions, one in spring and one in fall, with four sample events below.

Table 1. Date and results for sites sampled in weekly eDNA monitoring during the 2012 season.

Date Sampled	Site Sampled	# Samples Collected	Date Reported	Silver Carp Results	Bighead Carp Results
22-May	Lake Calumet & Little Calumet River	114	7-Jun	17 positive; 97 negative	Zero positive; 114 negative
11-Jun	North Shore Channel & Lake Calumet	99	28-Jun	4 positive; 110 negative	Zero positive; 114 negative
25-Jun	Lake Calumet & Little Calumet River	114	6-Jul	7 positive (all from Lake Calumet); 107 negative	Zero positive; 114 negative
10-Jul	Chicago Lock/Bubbly Creek & North Shore Channel	114	30-Jul	9 positive; 105 negative	Zero positive; 114 negative
11-Jul	Lake Calumet & Lake Calumet Golf Course Pond	57	30-Jul	3 positive (1 from golf course pond); 54 negative	Zero positive; 57 negative
24-Jul	Lake Calumet	56	6-Aug	3 positive; 53 negative	Zero positive; 56 negative
7-Aug	Chicago Lock/Bubbly Creek	57	22-Aug	Zero positive; 57 negative	Zero positive; 57 negative
20-Aug	Lake Calumet & Little Calumet River	114	19-Sep	8 positive (all from Lake Calumet); 106 negative	Zero positive; 114 negative
11-Sep	Chicago Lock/Bubbly Creek & North Shore Channel	114	1-Oct	30 positive; 84 negative	Zero positive; 114 negative
17-Sep	Lake Calumet & Little Calumet River	114	12-Oct	16 positive; 98 negative	Zero positive; 114 negative
2-Oct	Chicago Lock/Bubbly Creek & North Shore Channel	114	22-Oct	15 positive; 80 negative (19 discarded due to contamination)	Zero positive; 95 negative
15-Oct	North Shore Channel	57	25-Oct	8 positive; 49 negative	Zero positive; 57 negative
22-Oct	Lake Calumet & Little Calumet River	86	7-Nov	29 positive; 56 negative (1 discarded due to contamination)	4 positive; 81 negative (1 discarded due to contamination)

Table 2. Labor expended, sampling effort, and results for individual reaches sampled in weekly eDNA monitoring during 2012.

			Labor Expended		Sample Effort		Results (Negative or Positive)				
							Bighead Carp		Silver Carp		
				Estimated	Samples Collected	Total Effort	Negative	Positive	Negative	Positive	
Sample Reach	Dates	Location	Persons	person-hours	(*N*)	(Liters)	(*N*)	(*N*)	(*N*)	(*N*)	**NOTES**
Upstream of Electric Barrier											
Chicago Lock to Bubbly Creek	7/10; 8/6; 9/11; 10/2	CAWS									
eDNA Sampling			3	33.75	228	456	209	0	179	30	19 samples (10/2/2012) discarded due to contamination
eDNA Filtering			4	48	228	456					
North Shore Channel	6/11; 7/10; 9/11; 10/2; 10/15	CAWS									
eDNA Sampling			3	29.25	285	570	285	0	252	33	
eDNA Filtering			4	56	285	570					
Lake Calumet	5/22; 6/11; 6/25; 7/11; 7/23; 8/20; 9/17; 10/22	CAWS									
eDNA Sampling			3	83.25	407	814	402	4	329	77	1 sample (10/22/2012) discarded due to contamination
eDNA Filtering			4	98	407	814					
Lake Calumet (golf course pond)	7/11;	CAWS									
eDNA Sampling			3	3	14	28	14	0	13	1	
eDNA Filtering			4	6	14	28					
Little Calumet River North Leg	5/22; 6/25; 8/20; 9/17; 10/22	CAWS									
eDNA Sampling			3	30.75	276	552	276	0	263	13	
eDNA Filtering			4	40	276	552					

Table 3. Descriptive statistics for samples testing positive for silver carp DNA and negative for Asian carp DNA in 2012.

	Negative Samples				Positive Samples			
Environmental Parameter	**N**	**Mean**	**SD**	**Range**	**N**	**Mean**	**SD**	**Range**
Temperature (°C)	1,020	22.3	4.0	14.3 - 30.3	153	20.1	4.4	11.3 - 28.9
Channel Depth (m)	1,020	2.5	2.4	0.0 - 7.3	153	3.0	2.7	0.0 - 8.4
Dissolved Oxygen (mg/L)	884	7.9	2.7	2.5 - 13.3	147	6.2	3.2	0.0 - 12.6
Conductivity (µS/cm)	979	559.0	221.7	115.6 - 1002.4	151	525.6	234.3	57.0 - 994.2
pH	735	7.8	0.4	7.0 - 8.6	100	7.7	0.4	6.9 - 8.5

Table 4. Descriptive statistics for samples testing positive for bighead carp DNA and negative for Asian carp DNA in 2012.

	Negative Samples				Positive Samples			
Environmental Parameter	**N**	**Mean**	**SD**	**Range**	**N**	**Mean**	**SD**	**Range**
Temperature (°C)	1,020	22.3	4.0	14.3 - 30.3	4	13.3	0.2	12.9 - 13.7
Channel Depth (m)	1,020	2.5	2.4	0.0 - 7.3	4	2.0	3.5	0.0 - 9.0
Dissolved Oxygen (mg/L)	884	7.9	2.7	2.5 - 13.3	4	1.6	0.1	1.4 - 1.8
Conductivity (µS/cm)	979	559.0	221.7	115.6 - 1002.4	4	292.5	4.0	284.5 - 300.5
pH	735	7.8	0.4	7.0 - 8.6	-	-	-	-

Larval Fish and Productivity Monitoring in the Illinois Waterway

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Steven E. Butler, Jonathan A. Freedman, Matthew J. Diana, David H. Wahl; Illinois Natural History Survey

Participating Agencies: Illinois Natural History Survey (lead), Eastern Illinois University (support), Western Illinois University (support).

Introduction: 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. Larval fish sampling is being used to assess the timing and extent of Asian carp reproduction in the Illinois River. 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.
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.
3) Examine relationships among nutrients, phytoplankton, and zooplankton density in the Illinois Waterway.

Methods: Larval fish and productivity sampling occurred at 14 sites throughout the Illinois Waterway (Figure 1). Sampling was conducted at bi-weekly intervals from May to October. Four larval fish samples were collected at each site on each sampling date. Sampling transects were located on each side of the river channel, parallel to the bank, at both upstream and downstream locations within each study site. Samples were collected using a 0.5 m-diameter ichthyoplankton push net with 500um mesh. Fish eggs and larvae were collected in a meshed tube at the tail end of the net, transferred to sample jars, and preserved in 90-percent ethanol. The presence of any eggs was noted and all eggs retained for future analyses. Larval fish were

identified to the lowest possible taxonomic unit in the laboratory. Larval fish densities were calculated as the number of individuals per m^3 of water sampled.

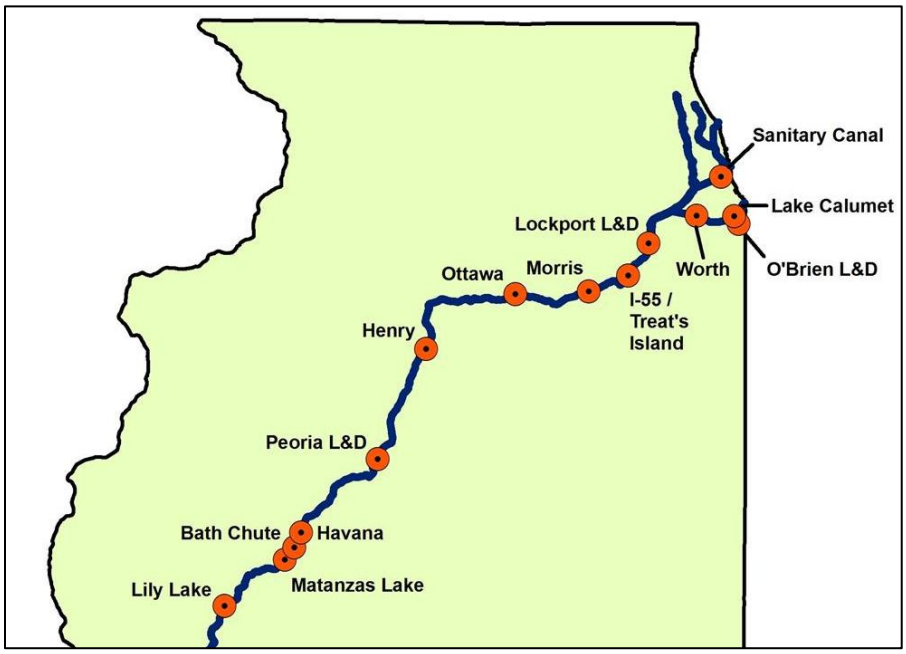


Figure 1. Map of larval fish and productivity sampling sites in the Illinois Waterway.

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

Results: In 2012, larval fish samples were collected from May 1 – October 18. Over 600 ichthyoplankton samples were collected, capturing over 25,000 larval fish. Larval fish densities were highest in May and June, but declined substantially after July (Figure 2). Larval and early-juvenile Asian carp (n = 396) were collected from multiple sites in the LaGrange Reach in May and June. Additionally, a single Asian carp egg was collected in a larval fish sample from Henry (Peoria Pool) in May. As in previous years, clupeids, primarily Gizzard Shad, were the most numerous larval fish taxa collected during 2012 (> 80% of all larval fish sampled). Cyprinid larvae, excluding Asian carp, were also abundant at most sites, and Centrarchid larvae, primarily *Lepomis* species, were common in the ichthyoplankton drift upstream of the Peoria Pool. Lesser numbers of Catostomids, Sciaenids, Moronids, Percids, Ictalurids, and Atherinids were also captured in larval fish samples (Figure 3).

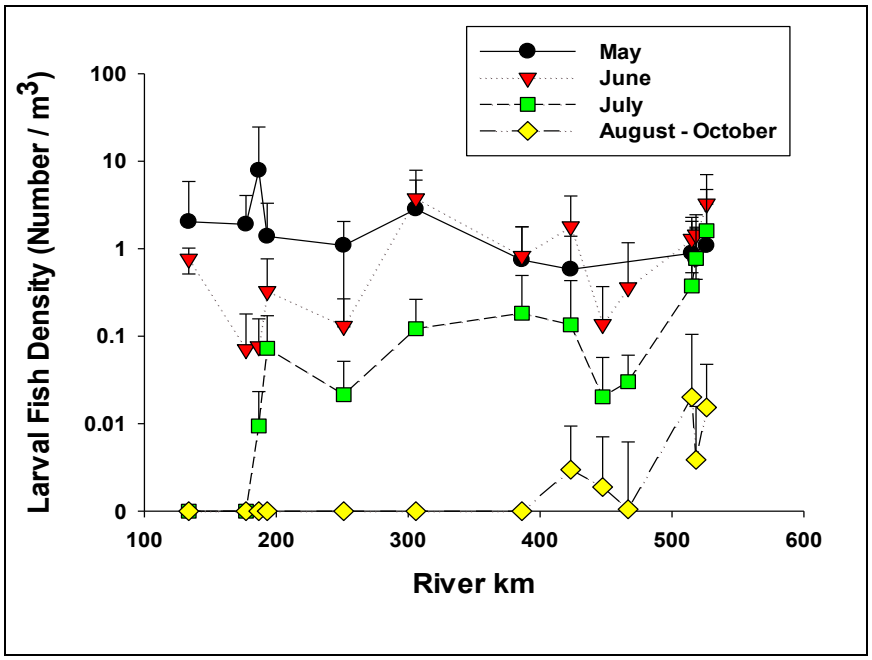


Figure 2. Monthly mean (± SD) densities of larval fish (all taxa) in the Illinois Waterway during 2012. River km is measured as distance upstream from the Mississippi River.

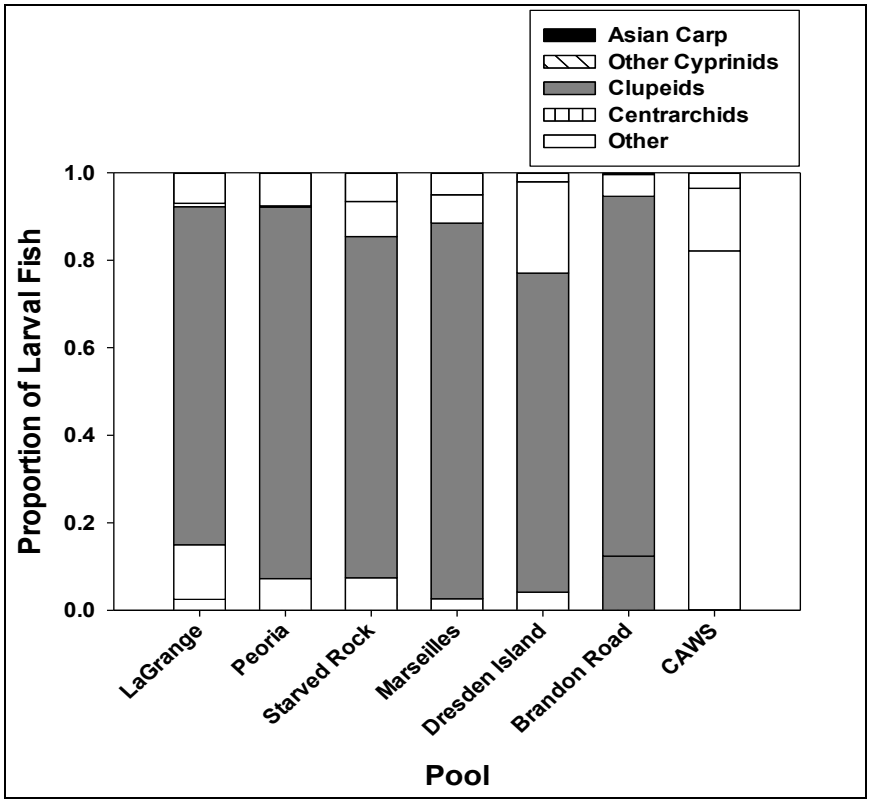


Figure 3. Taxonomic composition of larval fish captured in ichthyoplankton samples in each navigation pool of the Illinois Waterway during 2012.

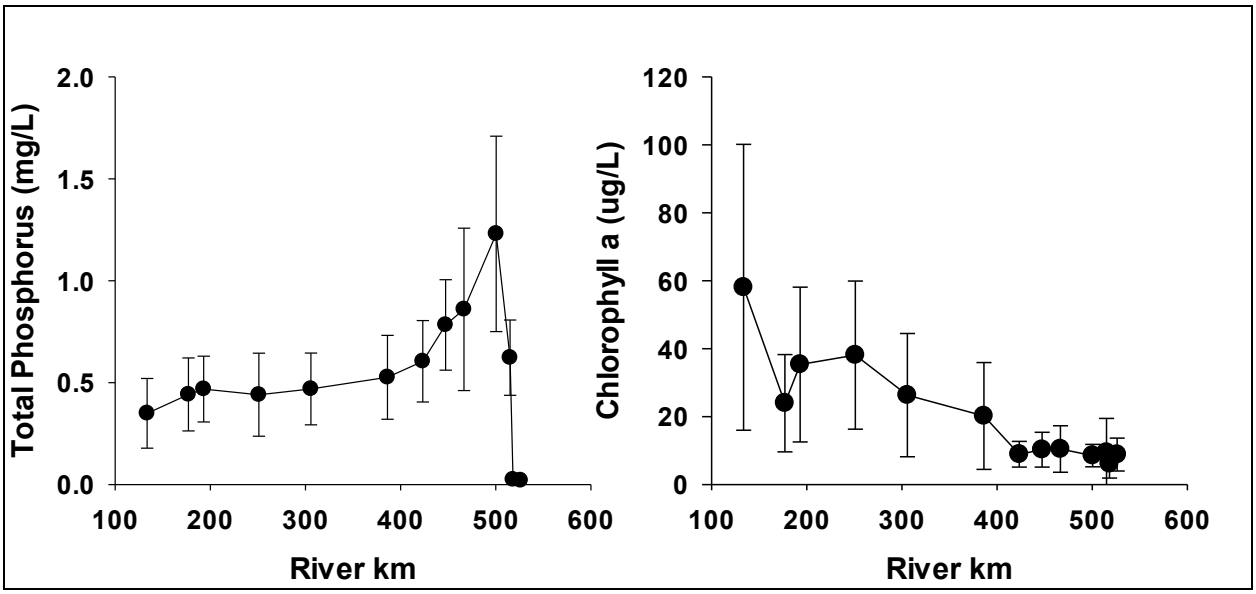


Figure 4. Mean (± SD) total phosphorus and chlorophyll *a* concentrations in the Illinois Waterway during 2011. River km is measured as distance upstream from the Mississippi River.

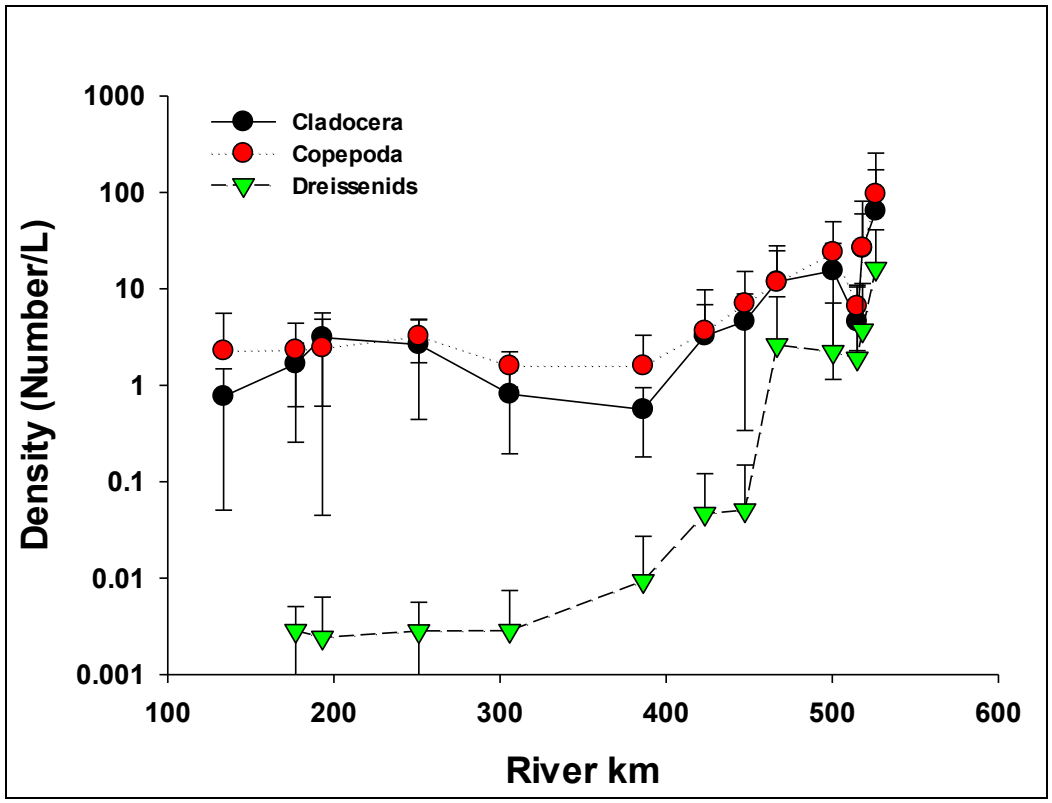


Figure 5. Mean densities (± SD) of macrozooplankton groups observed in the Illinois Waterway during 2011. River km is measured as distance upstream from the Mississippi River.

Productivity sampling largely coincided with larval fish sampling during 2012, and sample processing from 2012 is ongoing. Analysis of 2011 data revealed that total phosphorus concentrations increased with increasing distance upriver and were highest in the Des Plaines River and in the lower CAWS, but phosphorus concentrations declined to their lowest observed levels at sites closest to Lake Michigan (Figure 4). Phosphorus and chlorophyll concentrations were not found to be correlated, with the highest chlorophyll concentrations occurring in the lower Illinois River (Figure 4). Cladoceran and copepod densities varied little among sites in the Illinois River, but increased in abundance in the Des Plaines River and were highest in the CAWS. Densities of dreissenid veligers were relatively low in the Illinois River, but increased substantially in the Des Plaines River and in the CAWS. Densities of all zooplankton groups were highest in the Little Calumet River and in Lake Calumet (Figure 5).

Discussion: A higher number of Asian carp larvae were collected in 2012 than in previous sampling years. Asian carp larvae were found at only a single site on a single sampling date in both 2010 and 2011, but were present at multiple sites across several weeks during 2012, suggesting that conditions in the Illinois River may have been more conducive to reproduction in 2012 than in previous years. A single Asian carp egg containing a developing larva was collected at Henry, indicating that at least some Asian carp spawning occurred in the Peoria Pool in 2012. As in previous years, no evidence of Asian carp reproduction was observed in any upstream pools, and no Asian carp eggs or larvae were collected in the CAWS. Despite the higher number of larvae sampled, recruitment to the juvenile stage appears to have again been poor in 2012 (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 5 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. Phosphorus concentrations are highest in the CAWS, but the lack of correlation between phosphorus and chlorophyll *a* concentrations indicated that other factors (e.g., water residence time, depth, turbidity, other limiting nutrients, etc.) are contributing to observed patterns in chlorophyll *a* concentrations, which were highest in the lower Illinois River. High chlorophyll *a* concentrations may make the lower Illinois River particularly well suited to silver carp, which are capable of filtering phytoplankton. Zooplankton densities appear to remain fairly constant among sites in the Illinois River, but were higher at sites in the Des Plaines River and the CAWS, with the highest densities of all zooplankton groups being observed in the Little Calumet River and in Lake Calumet. These areas 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. Productivity samples from 2012 are still being processed and will allow for a more thorough evaluation of productivity patterns once this data becomes available.

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. Expanding larval fish sampling to 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. Continued productivity sampling will allow for a more thorough analysis of patterns in potential Asian carp food resources. Data from 2012 is still being processed 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 600 larval fish samples were collected from 13 sites across the length of the Illinois Waterway during May – October, 2012
- 25,612 larval fish were collected in 2012, including 396 larval Asian carp
    - Larval Asian carp were only collected in the LaGrange Pool in May – June
    - A single Asian carp egg was collected at Henry (Peoria Pool) in May
- 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

Brennan Caputo, Michael A. McClelland, David Wyffels, Tristan Widloe, Blake Ruebush, John Zeigler, Victor Santucci, and Kevin Irons; Illinois Department of Natural Resources
and
Jonathan A. Freedman, Steven E. Butler, Matthew J. Diana, and David H. Wahl;
Illinois Natural History Survey

Participating Agencies: Illinois Department of Natural Resources and Illinois Natural History Survey (co-leads); 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 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 flooding events.

Successful reproduction is 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 as larval fish may be washed into the CSSC upstream of the electric barrier system 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 ¼-inch mesh fencing used for the separation project. Larvae washed into the CSSC would likely be transported downstream past the electric barrier system during flooding, but these fish might become established in the lower Lockport Pool, recruit to the juvenile life stage, and challenge the electric barrier system. 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 used multiple gears suitable for sampling small fish to:

1) Determine whether Asian carp young 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, 2012 sampling for young-of-year and juvenile Asian carp occurred 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, Rapid Response Actions in the CAWS, Des Plaines River and Overflow Monitoring Project, and Barrier Maintenance Fish Suppression Project. See individual project summary reports and the 2012 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 electric barrier system occurred twice monthly from March-December in 2012 at five stations and included 30 15-minute transects. Random site monitoring occurred in four reaches that encompassed the entire 76 miles of the CAWS upstream of the electric barrier system, and consisted of 72 15-minute electrofishing transects. Fifty-nine total hours of electrofishing was completed over five rapid response actions in June, July, and 3 in October of 2012. Electrofishing at fixed sites downstream of the electric barrier system occurred monthly from March-November in 2012 at four sites in each of Lockport, Brandon Road, Dresden Island, and Marseilles pools (16 15-minute transects per month). A total of 12.6 hours of electrofishing was completed in the upper Des Plaines River downstream from Hofmann Dam. Three barrier maintenance fish sampling events occurred in the Lockport Pool in May, June and November 2012. Electrofishing for these events included 8 transects totaling 8 hours of sampling at the electric barrier system.

Standard electrofishing protocols were modified such that schools of small fish <6 inches long (typically Gizzard Shad) were subsampled by netting a portion of each school encountered during each electrofishing run. Netted small fish were held in a holding tank and examined individually for the presence of Asian carp before being returned to the waterway. Keeping small Gizzard Shad tallies (<6) separate from larger fish provided an estimate of the relative abundance of young Asian carp, if present, in each sample of small fish.

In addition to electrofishing, small fish were targeted with mini-fyke nets, small mesh experimental gill nets, push trawls, small mesh fyke nets, fyke nets, small mesh purse seines, midwater trawls, cast nets, and beach seines in the gear efficiency study. Each site visit included eight 4-hour gill net sets, eight mini-fyke net-nights, eight trap net nights, four purse seine hauls, four 5-minute midwater trawl tows, 3-4 cast net throws, and 3-4 beach seine hauls (see Gear Efficiency Report).

Results and Discussion: Young Asian carp were targeted with six gears in 2010, eight gears in 2011 and ten gears in 2012. Sampling included active gears, such as electrofishing, cast nets, seining, and trawling, and passive gears, such as experimental gill nets, trap nets, fyke nets and mini-fyke nets. Electrofishing accounted for the most effort with 402.5 hours combined for Illinois River, Upper Des Plaines River and CAWS (Table 2). Sampling with other gears also extended throughout the waterway and was included in gear evaluation, rapid response, and barrier maintenance monitoring efforts. Sampling effort was highest in the CAWS upstream of the electric barrier system and lowest in the upper Des Plaines River between Hofmann Dam and the CSSC-Des Plaines River confluence (Table 2).

No juvenile Asian carp <12 inches long were captured in 2010 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) and they may reflect poor Asian carp recruitment in the waterway over the past three years. A total of four post-larval Silver Carp young-of-the-year specimens were identified from three collections made in June 2012. All three collections were made in the Peoria pool, one in the vicinity of the town of Henry, Illinois and two near the town of Chillicothe, Illinois. Henry Illinois is about 106 miles from the electric barrier system and it represents the farthest upstream detection of Asian carp juveniles (<12 inches long) in the Illinois Waterway in recent years. In the past three years, 101,921 Gizzard Shad <6 inches long were examined in the CAWS and Illinois Waterway upstream of Starved Rock Lock and Dam and no young Asian carp were detected.

Recommendations: While these results are encouraging in our efforts to prevent Asian carp from establishing populations in the CAWS and Lake Michigan, they likely 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.

Table 1. Number of juvenile Bighead Carp, Silver Carp, hybrid Bighead 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 Unidentified Asian Carp, Bighead Carp, 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	Silver 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

Project Highlights:

- Sampled for young Asian carp in 2010, 2011, and 2012 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, midwater trawl, beach seine, and cast net) and passive gears (experimental gill nets, mini-fyke nets, and trap nets). Completed 1,070 hours of electrofishing across years and sites.
- Examined 101,921 Gizzard Shad <6 inches 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 two post larval Silver Carp in the Peoria Pool near Henry, Illinois (river mile 194) over 100 downstream from the electric barrier system.
- Recommend continued monitoring for young Asian carp, and a new project to enhance understanding of young Asian carp distribution and habitat selection.

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 as "very certain". 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 barrier system are sufficient to stop large bodied fish 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). For this reason there exists some concern that small sized Asian carp, if present, might represent a threat to breach the electric barrier system. 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 electric barrier system. Additionally, there is an ongoing need to understand the reproduction of these species in the IWW so that managers might better target small sized fish for eradication or other management actions in the future.

The purpose of this study was to establish where young (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 300 mm 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: We used mini-fyke nets, large-frame, small-mesh fyke nets, electrofishing, and push trawls to collect fish. Mini-fyke nets and large-frame, small-mesh fyke nets were set and fished overnight. Electrofishing consisted of 15 minute daytime pulsed-DC boat electrofishing runs using a Smith Root Type VI-A electrofishing system. Push-trawl samples were conducted 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 foot rope, and an effective net fishing width 1.8 m across. Trawl hauls were between 25 and 100 meters in length and varied with the amount of fishable habitat present at a given location.

Sample sites were selected randomly within side channel, contiguous backwater and isolated backwater habitats of the upper and middle IWW using U.S. Geological Survey (USGS) Long Term Resource Monitoring Program Aquatic Areas data. We outfitted a sampling boat with a Pro-Drive 36 horsepower surface drive outboard motor in order to access and sample very shallow backwater areas. This shallow water boat allowed access to areas too shallow for traditional fisheries boats to navigate.

All fish collected were identified to the lowest possible taxonomic level, enumerated, and released. Some collections of very small bodied fishes were preserved and returned to the laboratory for identification and enumeration. Small Asian carp specimens captured were preserved and retained to provide a permanent physical, geographic, and temporal record. 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 a YSI Professional Series multi-meter included: temperature, salinity, specific conductance, dissolved oxygen, and pH.

Netting and push-trawl sampling occurred in two rounds of effort within selected pools of the IWW (Peoria, Starved Rock, Marseilles, and Dresden Island) sampled once during June and

July and again during August and September. Electrofishing sampling was done in three rounds of sampling with each pool being sampled from June and July, August and September, and again during 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: A total of 72,015 fish were collected from 4 June to 1 November at 458 sites distributed among the Peoria, Starved Rock, Marseilles, and Dresden Island Pools of the IWW. Sampling consisted of 209 electrofishing runs (52.25 hours of effort); 88 experimental push trawl runs; 184 net nights of mini-fyke nets, and 52 net nights with large frame, small meshed fyke nets. Eighty species and 3 hybrid combinations were identified. Nine species collected were non-native. A total of four post-larval Silver Carp young of year (YOY) specimens were identified from three mini-fyke net collections made during 4 to 6 June 2012. All three collections were made in the Peoria pool, one in the vicinity of the town of Henry, Illinois (River Mile 194) and two near the town of Chillicothe, Illinois (River Mile 184). All four of the small Asian carp specimens were identified as Silver Carp by J.G. Stewart and Dr. B.M. Burr based on morphological characteristics (it should be noted however that hybrid Bighead Carp x Silver Carp are relatively common in the IWW and therefore the possibility exists that these four YOY specimens could be hybrids). Sizes of the specimens range from 16-21mm total length (TL). No other small Asian carp were collected during this study. Due to the lack of appropriate sized small Asian carp specimens, telemetry was not possible during the 2012 field season. It is worth noting that throughout the 2012 sampling season we observed many Silver Carp that were in the range of 300 to 400 mm TL and therefore just outside the operational definition of 300 mm as a "small" Asian carp.

The 2012 field season corresponded to a remarkably dry and hot period of time with the U.S. experiencing the warmest year on record and with the Illinois River drainage characterized as moderately to severely dry from March through August (NOAA National Climatic Data Center). There was one period of increased discharge and gage height beginning on 5 May, peaking on 12 May, and returning to base flow 25 May (USGS Water Resources). The four specimens of YOY Silver Carp that we captured were collected from 4 to 6 June approximately three weeks after the spike in river discharge in May. As a result of the dry weather, the Illinois Waterway did not experience any further significant flood pulse events during 2012; water levels were observed to remain low and relatively stable over the course of the field season. Bighead Carp and Silver Carp are generally considered to be dependent on a rising hydrograph to initiate spawning (Kolar et al. 2007). Water levels in the Illinois Waterway during most of 2012 were not conducive to the initiation of Asian carp spawning. Personal communications with fishery biologists working in the Illinois River Basin and in other drought affected river basins indicate that Asian carp spawning and recruitment was all but non-existent in those areas as well. Therefore any conclusions drawn about the distribution of small bodied Asian carps must necessarily be colored by the fact that 2012 was a very dry year which could have prevented widespread Asian carp reproduction throughout the entire river system.

The collection of YOY Silver Carp suggests that at least some limited reproduction occurred in the spring of 2012. The fact that only four specimens were collected suggests that Asian carp reproduction was not widespread or common in the reach of river we examined. The locations where the four specimens were collected do not extend the distribution of small Asian carp further upstream than previously documented as juvenile Asian carp have previously been caught in the vicinity of Henry, Illinois (J. Freedman unpublished INHS data). The two YOY specimens collected at River Mile 194 do however represent the farthest upstream documented occurrence of YOY silver carp in the IWW (total lengths of 16, and 19 mm). The previously collected specimen from the Henry area was a much larger and older specimen (291 mm Silver Carp collected 17 June 2011) presumably in the second year of life. It is reasonable to assume that the collection of the YOY specimens near Henry and Chillicothe indicate that spawning occurred at some point upstream of their capture location.

Numerically dominant species collected included YOY Gizzard Shad, Bullhead Minnow, Spotfin Shiner, YOY sunfish, YOY Buffalo spp., Gizzard Shad, YOY Bluegill, Emerald Shiner, Channel Shiner and Bluntnose Minnow. State threatened and endangered fish species captured included the threatenedRriver Redhorse (N=3) and Banded Killifish (N=95); and the endangered Blacknose Shiner (N=58) and Pallid Shiner (N=1). Of 72,015 specimens collected, nearly half (35,142) were young of year 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.

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 in the uppermost limits of the IWW for YOY and juvenile Asian carp is needed and should provide valuable knowledge about the source pool(s) for juvenile Asian carp in the middle and upper IWW.

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 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 dispersal barriers.

Project Highlights:

- Results include a total of 72,015 fish specimens collected and examined. Eighty species and 3 hybrid combinations were identified. Nine species collected were non-native exotics.
- A total of four post-larval Silver Carp (*Hypophthalmichthys molitrix*) YOY specimens were identified from three mini-fyke net collections made during 4 to 6 June 2012. All three collections were made in the Peoria pool, one in the vicinity of the town of Henry, IL and two near the town of Chillicothe, IL. Sizes of the specimens range from 16-21mm total length. No other YOY Asian carp were collected during this study.
- The collection of YOY silver carp suggests that at least limited reproduction occurred in the spring of 2012. The fact that only four specimens were collected suggests that Asian carp reproduction was not widespread or common in the reach of river we examined during 2012. The locations where the four specimens were collected represent the furthest upstream documentation of YOY Silver Carp in the IWW.
- Recommend continued monitoring for small Asian carp in the IWW.

Fixed Site Monitoring Downstream of the Dispersal Barrier

Blake C. Ruebush, John M. Zeigler, David Wyffels, Michael A. McClelland,
Tristan Widloe, Brennan Caputo, Victor Santucci, and Kevin Irons;
Illinois Department of Natural Resources

Participating Agencies: Illinois Department of Natural Resources (lead); 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 barrier system. 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 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 2012 have contributed to our understanding of Asian carp abundance and distribution downstream of the electric barrier system 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 barrier system;
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 Master Plan); and
4) Obtain information on the non-target fish community to help verify sampling success, guide modifications to sample locations, and assist with detection probability modeling and gear evaluation studies.

Methods: The sample design included intensive electrofishing and netting at four fixed sites in each of four pools below the electric barrier system (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).

Electrofishing Protocol – Electrofishing samples in 2012 occurred monthly 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 2012, netting took place once per month from March through November in all four pools. We conducted net sampling at additional locations downstream of the electric barrier system in 2012 to better monitor Asian carp abundance and distribution in pools below the electric barrier system. Contracted commercial fishers were used for net sampling at all fixed sites. Gear included large mesh (3.0-4.0 inches) trammel or gill nets 8 feet high and in lengths of 100 or 200 yards. An IDNR biologist or technician was assigned to each commercial net boat to monitor operations, record data, and check for ultrasonically-tagged and jaw-tagged Asian carp and Common Carp (left pelvic fin clips or telemetry surgery wounds on the ventral left area of the fish, posterior to the pelvic fin and anterior to the anal opening). 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 150 yards 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. Nets were deployed at four fixed sites within each of the target pools, once per month, starting in August and concluding in December. All netting was conducted by IDNR biologists at all fixed sites.

Hoop nets were 6 feet in diameter, composed of 7 hoops, with 2.5-in bar mesh and when extended were 22 feet long. An anchor, followed by a 50 foot line was connected to the cod end of the net. Water current kept the nets open, but when water velocities were too slow a bridle and block were used on the downstream end of the net. Nets were set in main-channel borders and below locks and dams in $\geq$ 6 feet 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 0.125 inches in diameter and was nylon coated with green dip. A 15 feet long, by two feet high lead was connected to the cab. When fully extended the cab was 10 feet long, making the entire net 25 feet 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 1,585 person-hours were expended completing 94.5 hours of electrofishing at fixed sites downstream of the electric barrier system from 2010-2012. Electrofishing captured 35,923 fish representing 81 species, and

three hybrid groups (Table 2). Gizzard Shad, Bluegill, Emerald Shiner, Threadfin Shad, Bluntnose Minnow, Common Carp, Green Sunfish, Largemouth Bass, Spotfin Shiner, Smallmouth Buffalo, and Bullhead Minnow accounted for over 90% percent of the total catch in 2012.

Fixed site electrofishing catch-per-unit-effort (CPUE) increased from 2011 (CPUE = 384.4 fish / hour) to 2012 (CPUE = 466.5 fish / hour) (Table 1). Greater electrofishing CPUE in 2012 might be linked to lower river stages. No Bighead 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 185 Silver Carp were sampled by electrofishing at fixed sites in Marseilles Pool from 2010-2012. In 2012, a total of 6,270 Gizzard Shad ≤ 6 inches were examined at fixed sites downstream of the electric barrier system and detected no Asian carp YOY.

Although no live Silver Carp were captured or seen upstream of the Brandon Road Lock and Dam, two dead Silver Carp were observed by a US Army Corps of Engineers biologist electrofishing at fixed sites downstream of the barrier in July 2011. The dead Silver Carp were located on the deck of an upstream–bound tow that was staged in the Brandon Road Pool just downstream of the Lockport Lock. The carp apparently were on the barge deck for some time, as they were decomposing and releasing body fluids into the water.

Gill and Trammel Netting Effort and Catch – An estimated 2,796.5 person-hours were expended setting and running 81.1 miles of net at fixed sites and additional netting locations downstream of the electric barrier system from 2010-2012. Netting caught 4,787 fish representing 25 species (Table 3). Common Carp, Bighead Carp, Smallmouth Buffalo, Silver Carp, and Bigmouth Buffalo accounted for 92.2% of the total catch in 2012.

No Bighead or Silver Carp were caught by netting in the Lockport or Brandon Road pools. Catches of Bighead Carp at fixed and additional sampling sites increased downstream of the Brandon Road Lock and Dam, whereas catches of Silver Carp were limited to samples from the Marseilles Pool. Four Bighead Carp were collected in the Dresden Island Pool in 2012. Net catches of Bighead Carp in the Marseilles Pool were greater ($N = 105$) than Dresden Island Pool catches in 2012. Similarly, additional netting efforts caught fewer Bighead Carp in Dresden Island Pool ($N = 12$) compared to Marseilles Pool ($N = 29$) in 2011. In 2012, no Bighead Carp were captured during additional netting in Dresden Island Pool, however Bighead Carp were captured in Marseilles Pool ($N = 41$). Higher catches of Asian carp during 2011 compared to 2010 were due to increased netting effort at fixed sites in 2011, sampling at additional netting locations downstream of the electric barrier system (equal to nearly 1,000 person-hours and >24 miles of net), and protracted sampling into late fall 2011. Fixed site netting CPUE decreased from 2011 (CPUE = 4.80 fish / 100 yards of net) to 2012 (CPUE = 1.87 fish / 100 yards of net) (Table 1). Netting continued through November in all pools in 2012.

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 barrier system (Lockport, Brandon Road, Dresden Island, and Marseilles) in 2012 only. An estimated 862.5 person hours were expended setting and running 64 hoop nets and 64 mini-fyke nets for 128 and 68 net nights,

respectively (Table 1). Due to needed boat maintenance, mini-fyke nets set in Brandon Road Pool in October 2012 were fished for two net nights per net rather than one net night per net.

During the 2012 hoop netting, 88 fish, representing eight species, were captured (Table 4). Common Carp, Channel Catfish, Smallmouth Buffalo, Bighead Carp, and Freshwater Drum accounted for over 90% of the 2012 hoop net catches. No Asian carp were captured in hoop nets in the Lockport, Brandon Road, or Dresden Island Pools. Bighead ($N = 6$) and Silver Carp ($N = 3$) were only captured in hoop nets in the Marseilles Pool in August 2012.

Mini-fyke nets captured 19,910 fish, representing 39 species and one hybrid group (Table 5). Bluegill, Pumpkinseed, Mosquitofish, Bluntnose Minnow, Orangespotted Sunfish, and Spotfin Shiner accounted for over 90% of the 2012 mini-fyke net catches. No YOY or adult Bighead or Silver Carp were captured in mini-fyke nets in any pool.

Results of electrofishing and net sampling with contracted commercial fishers revealed patterns of Asian carp distribution and relative abundance in the Upper Illinois Waterway. Based on monitoring results to date, we would characterize abundance of Bighead and Silver Carp as rare in Lockport Pool below the electric barrier system (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 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 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 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. For this reason and to reduce propagule pressure on the electric barrier system located just 24 miles upstream, contracted commercial fishers directed most of their netting effort and removed the greatest quantity of Asian carp from Marseilles Pool during the past three years. Although Asian carp populations in the Marseilles Pool may be capable of spawning, we have no evidence in recent years that any successful reproduction has occurred in this or in other reaches of the Upper Illinois Waterway or CAWS. Extensive monitoring from 2010-2012 detected no Asian carp larvae upstream of Peoria Lock and Dam (river mile 158) and no juveniles above Henry, Illinois (river mile 190; over 100 miles from the Dispersal Barrier).

Recommendations: Extensive monitoring and removal efforts have allowed us to begin to characterize and manage the risk of Asian carp populations moving upstream toward the CAWS and Lake Michigan. Similar patterns in abundance among sampling gears (electrofishing and trammel/gill netting) and monitoring/removal projects (also see Barrier Defense Removal report) adds confidence to the finding that relative abundance of Asian carp decreased with upstream location in the waterway.

We recommend continued and increased monitoring of Asian carp populations at fixed sites downstream of the electric barrier system with electrofishing gear, hoop and mini-fyke netting, and contracted commercial fishers. We propose to start hoop and mini-fyke netting no later than June 2013. 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 increasing fixed site electrofishing below the electric barriers system to a bi-weekly schedule as well as conducting random electrofishing twice per month. We also propose to increase fixed and random contracted commercial netting in the downstream pools (Dresden Island and Marseilles). Increased sampling, outside of barrier defense, will also increase removal efforts in the Upper Illinois Waterway and reduce propagule pressure on Lake Michigan.

Project Highlights:

- Estimated 5,267 person-hours spent sampling at fixed sites and additional netting locations downstream of the electric barrier system from 2010-2012.
- 94.5 hours spent electrofishing and 81.1miles of trammel/gill net deployed.
- Sampled 60,709 fish, representing 84 species and four hybrid groups.
- No Bighead or Silver Carp were captured by electrofishing or netting in Lockport and Brandon Road pools.
- One Bighead Carp captured and no Silver Carp captured or seen during electrofishing in Dresden Island Pool in 2010. A total of 25 Bighead Carp and no Silver Carp captured during contracted commercial netting at Dresden Island Pool fixed sites and additional netting locations. Detectable population front of mostly Bighead Carp located just north of I-55 Bridge at river mile 280 (47 miles from Lake Michigan). No appreciable change in upstream location of the population front in past five years.
- Sampled 17 Bighead Carp and 185 Silver Carp by electrofishing, and 455 Bighead Carp and 258 Silver Carp by netting at fixed sites and additional netting locations in Marseilles Pool. Presence of mature adults capable of spawning occurred in this pool about 55 miles from Lake Michigan. However, Asian carp larvae and juveniles were not detected upstream of Peoria Pool or less than 100 miles downstream of the electric barrier system and 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 start hoop and mini-fyke netting in June 2013. Also recommend shifting more sampling efforts from the CAWS to the Upper Illinois Waterway.

Table 1. Electrofishing, Fixed Gill and Trammel Netting, Additional Gill and Trammel Netting, Hoop Netting, Minnow Fyke Netting, and 30' Gill Netting efforts and catch summaries for 2012 fixed sites below the barrier.

Electrofishing Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	20 Mar - 15 Nov		19 Mar - 15 Nov	20 Mar - 15 Nov	
Person-days	16	16	27.5	26.5	86
Estimated person-hours	120	120	206	199	645
Electrofishing hours	9	9	9	9	36
Samples (transects)	36	36	36	36	144
All Fish *(N)*	4408	1842	4967	5579	16,796
Species *(N)*	27	33	37	55	68
Hybrids *(N)*	1	1	1	1	1
Bighead Carp *(N)*	0	0	0	3	3
Silver Carp *(N)*	0	0	0	53	53
CPUE (fish/hour)	489.7	204.6	551.8	619.8	466.5

Additional Gill and Trammel Netting Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	7 Nov - 8 Nov	10 Aug - 7 Dec	11 May - 5 Oct	30 Mar - 26 Oct	
Person-days	3	30	36	40	109
Estimated person-hours	22.5	225	270	300	817.5
Samples (net sets)	8	40	45	49	142
Total miles of net	0.909	4.43	5.68	6.16	17.187
All Fish *(N)*	11	108	196	246	561
Species *(N)*	1	4	8	9	11
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	0	41	41
Silver Carp *(N)*	0	0	0	24	24
CPUE (fish/100 yard of net)	0.68	1.38	1.96	2.26	1.85

Fixed Gill and Trammel Netting Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	29 Mar - 21 Nov	29 Mar - 21 Nov	29 Mar - 21 Nov	29 Mar - 21 Nov	
Person-days	13.5	13.5	13.5	13.5	54
Estimated person-hours	101	101	101	101	404
Samples (net sets)	36	36	36	36	144
Total miles of net	4.1	4.1	4.1	4.1	16.4
All Fish *(N)*	29	83	130	299	541
Species *(N)*	2	2	8	11	14
Hybrids *(N)*	0	1	1	0	1
Bighead Carp *(N)*	0	0	4	105	109
Silver Carp *(N)*	0	0	0	74	74
CPUE (fish/100 yard of net)	0.40	1.15	1.80	4.15	1.87

Hoop Netting Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	27 Aug - 3 Dec	29 Aug - 3 Dec	29 Aug - 5 Dec	27 Aug - 3 Dec	
Person-days	20	20	20	18	78
Estimated person-hours	150	150	150	135	585
Net Nights	32	32	32	32	128
Samples (net sets)	16	16	16	16	64
All fish *(N)*	18	20	17	33	88
Species *(N)*	2	4	5	6	8
Hybrids *(N)*	0	0	0	0	0
Bighead Carp *(N)*	0	0	0	6	6
Silver Carp *(N)*	0	0	0	3	3
CPUE (fish/net)	1.13	1.25	1.06	2.06	1.38

Minnow Fyke Netting Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	27 Aug - 3 Dec	29 Aug - 3 Dec	29 Aug - 5 Dec	27 Aug - 3 Dec	
Person-days	20	20	16	18	74
Estimated person-hours	75	75	60	67.5	277.5
Net Nights	16	20	16	16	68
Samples (net sets)	16	16	16	16	64
All fish *(N)*	9,354	5,260	2,711	2,585	19,910
Species *(N)*	17	25	18	26	39
Hybrids *(N)*	0	1	1	1	1
Bighead Carp *(N)*	0	0	0	0	0
Silver Carp *(N)*	0	0	0	0	0
CPUE (fish/net)	584.63	328.75	169.44	161.56	311.09

Additional 30 Feet Deep Gill Netting Effort - 2012

	Pool				
	Lockport	Brandon	Dresden	Marseilles	Total
Sample Dates	7 Nov - 8 Nov				
Person-days	3				3
Estimated person-hours	22.5				22.5
Samples (net sets)	16				16
Total miles of net	0.91				0.91
All Fish *(N)*	12				12
Species *(N)*	2				2
Hybrids *(N)*	0				0
Bighead Carp *(N)*	0				0
Silver Carp *(N)*	0				0
CPUE (fish/100 yard of net)	0.75				0.75

Table 2. Total number of fish captured and percentage of total catch from 2012 and 2010-2012 totals for fixed site electrofishing below the dispersal barrier. *Common Carp were counted by observation

	2012						2010-2012	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Gizzard shad	3,190	996	1,679	2,220	8,085	48.1%	19,472	54.3%
Bluegill	70	124	958	584	1,736	10.3%	2,755	7.7%
Common carp	67	250	196	110	623	3.7%	2,023	5.6%
Emerald shiner	382	88	126	480	1,076	6.4%	1,703	4.7%
Smallmouth buffalo	0	0	63	312	375	2.2%	1,235	3.4%
Largemouth bass	88	15	273	132	508	3.0%	1,122	3.1%
Threadfin shad	14	11	706	107	838	5.0%	1,119	3.1%
Bluntnose minnow	134	33	448	221	836	5.0%	988	2.8%
Green sunfish	222	56	193	86	557	3.3%	817	2.3%
Spotfin shiner	7	27	42	347	423	2.5%	556	1.5%
Bullhead minnow	0	0	20	276	296	1.8%	358	1.0%
Smallmouth bass	3	5	35	55	98	0.6%	278	0.8%
Golden redhorse	0	0	3	45	48	0.3%	272	0.8%
River carpsucker	0	0	4	59	63	0.4%	269	0.7%
Bigmouth buffalo	0	0	1	92	93	0.6%	235	0.7%
Pumpkinseed	39	59	25	9	132	0.8%	220	0.6%
Channel catfish	5	18	16	25	64	0.4%	208	0.6%
Freshwater drum	2	14	8	16	40	0.2%	199	0.6%
Silver carp	0	0	0	53	53	0.3%	185	0.5%
Longnose gar	2	1	6	20	29	0.2%	182	0.5%
Yellow bullhead	21	29	31	0	81	0.5%	165	0.5%
Quillback	0	0	1	51	52	0.3%	163	0.5%
Spottail shiner	2	0	12	50	64	0.4%	138	0.4%
White bass	0	0	2	20	22	0.1%	125	0.3%
Hybrid sunfish	7	8	19	10	44	0.3%	96	0.3%
Oriental weatherfish	75	3	0	0	78	0.5%	88	0.2%
Shorthead redhorse	0	0	7	17	24	0.1%	83	0.2%
Golden shiner	32	1	24	8	65	0.4%	82	0.2%
Goldfish	2	20	9	0	31	0.2%	71	0.2%
Orangespotted sunfish	0	16	11	18	45	0.3%	71	0.2%
White sucker	2	29	0	0	31	0.2%	56	0.2%
Black crappie	0	0	13	13	26	0.2%	45	0.1%
Brook silverside	0	1	3	34	38	0.2%	45	0.1%
Mosquitofish	28	3	0	1	32	0.2%	35	0.1%
Rock bass	0	0	15	4	19	0.1%	34	0.1%
White crappie	0	1	1	11	13	0.1%	31	0.1%
Round goby	0	18	0	0	18	0.1%	27	0.1%
Northern hog sucker	0	0	0	4	4	0.0%	26	0.1%
Logperch	0	0	1	10	11	0.1%	22	0.1%
River shiner	0	0	0	18	18	0.1%	22	0.1%
Silver redhorse	0	0	0	1	1	<0.1%	22	0.1%
Shortnose gar	0	0	0	7	7	<0.1%	21	0.1%
Bighead carp	0	0	0	3	3	<0.1%	18	0.1%
Northern pike	1	2	0	0	3	<0.1%	17	<0.1%
Sand shiner	0	0	0	14	14	0.1%	15	<0.1%

Table 2. Continued.

	2012						2010-2012	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Black buffalo	0	0	4	2	6	<0.1%	14	<0.1%
Yellow bass	0	0	0	1	1	<0.1%	14	<0.1%
Blackstripe topminnow	0	3	7	0	10	0.1%	13	<0.1%
Mimic shiner	0	0	0	12	12	0.1%	12	<0.1%
Sauger	0	0	0	1	1	<0.1%	12	<0.1%
Skipjack herring						0.0%	12	<0.1%
Brown bullhead	2	3	3	0	8	<0.1%	11	<0.1%
Flathead catfish	0	0	0	2	2	<0.1%	11	<0.1%
White perch	0	0	0	1	1	<0.1%	11	<0.1%
Banded killifish	3	0	0	1	4	<0.1%	4	<0.1%
Black bullhead	1	2	1	0	4	<0.1%	4	<0.1%
Trout perch	0	0	0	3	3	<0.1%	4	<0.1%
Banded darter	0	0	0	1	1	<0.1%	3	<0.1%
River redhorse						0.0%	3	<0.1%
Spotted Gar	0	0	0	1	1	<0.1%	3	<0.1%
Suckermouth minnow						0.0%	3	<0.1%
Warmouth						0.0%	3	<0.1%
Blackside darter	0	0	0	1	1	<0.1%	2	<0.1%
Central mudminnow	0	2	0	0	2	<0.1%	2	<0.1%
Common shiner						0.0%	2	<0.1%
Redear sunfish						0.0%	2	<0.1%
Silver chub	0	0	0	2	2	<0.1%	2	<0.1%
Spotted sucker	0	1	0	0	1	<0.1%	2	<0.1%
Unidentified Notropis						0.0%	2	<0.1%
American eel	0	0	0	1	1	<0.1%	1	<0.1%
Alewife						0.0%	1	<0.1%
Bowfin						0.0%	1	<0.1%
Goldeye						0.0%	1	<0.1%
Greater redhorse	0	0	0	1	1	<0.1%	1	<0.1%
King Salmon						0.0%	1	<0.1%
Paddlefish						0.0%	1	<0.1%
Striped shiner	0	0	0	1	1	<0.1%	1	<0.1%
White perch hybrid						0.0%	1	<0.1%
Total Caught	4,408	1,842	4,967	5,579	16,796	100.0%	35,874	100.0%
Species	27	33	37	55	68		81	
Hybrid groups	1	1	1	1	1		3	

Table 3. Total number of fish captured and percentage of total catch from 2012 and 2010-2012 totals for fixed netting below the dispersal barrier. 2011 and 2012 data includes data from additional netting and 30' gill netting.

	2012						2010-2012	
	Pool				Number		Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent	Captured	Percent
Common carp	50	184	224	119	577	51.8%	2,233	46.6%
Smallmouth buffalo	0	2	71	35	108	9.7%	926	19.3%
Bighead carp	0	0	4	146	150	13.5%	621	13.0%
Silver carp	0	0	0	98	98	8.8%	282	5.9%
Bigmouth buffalo	0	0	3	91	94	8.4%	220	4.6%
Channel catfish	1	2	8	5	16	1.4%	131	2.7%
Black buffalo	0	0	1	1	2	0.2%	76	1.6%
Freshwater drum	0	1	7	8	16	1.4%	72	1.5%
Carp x goldfish hybrid	0	1	2	0	3	0.3%	63	1.3%
Grass carp	0	0	1	36	37	3.3%	58	1.2%
Goldfish	0	1	1	0	2	0.2%	33	0.7%
River carpsucker						0.0%	21	0.4%
Flathead catfish	0	0	1	3	4	0.4%	13	0.3%
Longnose gar	0	0	2	1	3	0.3%	9	0.2%
Quillback						0.0%	7	0.1%
Skipjack herring						0.0%	4	0.1%
Largemouth bass						0.0%	3	0.1%
Northern pike						0.0%	3	0.1%
Goldeye	0	0	0	2	2	0.2%	2	<0.1%
Walleye	0	0	1	0	1	0.1%	2	<0.1%
Hybrid Striped Bass						0.0%	2	<0.1%
Muskie	1	0	0	0	1	0.1%	1	<0.1%
Gizzard shad						0.0%	1	<0.1%
Shortnose gar						0.0%	1	<0.1%
Silver redhorse						0.0%	1	<0.1%
Spotted Gar						0.0%	1	<0.1%
Yellow bullhead						0.0%	1	<0.1%
Total Caught	52	191	326	545	1,114	100.0%	4,787	100.0%
Species	0	3	12	2	13		25	
Hybrid groups	0	0	2	0	2		2	

Table 4. Total number of fish captured and percentage of total catch from 2012 fixed hoop netting downstream of the dispersal barrier.

	2012					
	Pool				Number	
Species	Lockport	Brandon	Dresden	Marseilles	Captured	Percent
Common carp	15	8	5	1	29	33.0%
Channel catfish	0	9	4	9	22	25.0%
Smallmouth buffalo	0	0	6	12	18	20.5%
Bighead carp	0	0	0	6	6	6.8%
Freshwater drum	3	2	0	0	5	5.7%
Flahead catfish	0	1	1	2	4	4.5%
Silver carp	0	0	0	3	3	3.4%
River carpsucker	0	0	1	0	1	1.1%
Total Caught	18	20	17	33	88	100.0%
Species	2	4	5	6	8	
Hybrid groups	0	0	0	0	0	

Rapid Response Actions in the CAWS

Tristan Widloe, Victor Santucci, David Wyffels, Michael McClelland, Brennan Caputo, Matthew O'Hara, and Kevin Irons; Illinois Department of Natural Resources

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

Introduction: 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 MRRWG, and were not intended to be rigid triggers requiring immediate action. Final decisions to initiate rapid 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: Rapid response objectives were to:

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: Conventional and experimental gear response actions occurred in the CAWS upstream of the electric barrier system in 2012. A variety of gears were used, including pulsed-DC electrofishing, trammel and gill nets, deep water gill nets, a commercial seine, trap nets, hoop nets and Great Lake pound nets. Trammel and gill nets were typically 8-10 feet deep x 300 feet long with bar mesh sizes ranging from 2.75-4.5 inches. Deep water gill nets were 30 feet deep x 300 feet long with bar mesh sizes ranging from 2.75-3.5 inches. The commercial seine was 2,400-feet long x 30 feet deep and had a cod end made of 2.0-inch bar mesh netting. Trap nets had either 3x5 or 4x6-foot boxes and were equipped with single circular throats and 50-foot leads. Hoop nets were 22-feet long and had seven 6-foot diameter hoops with 2.5-inch bar mesh netting. Great Lake pound nets had a double heart configuration, elongated tunnels, custom

wing extensions that run to shore, custom leads that run parallel to shore, a 10x10-foot box with two mesh sizes of 1.5-inch and 2.5-inch square mesh. 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; see Fixed Site Monitoring Upstream of Dispersal Barrier report). However, in some responses we were able to leave nets fishing for longer duration, including over night, when recreational boating was temporarily suspended (e.g., Lake Calumet responses).

Results and Discussion: We completed five response actions in 2012: North Shore Channel, Chicago River and three response actions in Lake Calumet. Rotenone was not used during 2012 response actions.

Response actions were labor intensive and employed extensive sampling effort targeting any Asian carp that might be present in the waterway. We spent an estimated 1,630 person-hours on 2012 response actions (Table 1). Effort for all responses in 2012 was 59 hours of electrofishing (250 transects), 18.4 miles of trammel/gill net (180 sets), 1.4 miles of commercial seining (3 hauls), 7.6 trap net-days, 19.1 hoop net-days, and 3.6 pound net-days. Across all actions and gears in 2012, we collected 29,818 fish representing 53 species and 2 hybrid groups (Table 2). Gizzard Shad, Bluegill and Common Carp were the numerically dominant species sampled. No Bighead or Silver Carp were captured or observed during any of the response actions to date. In addition, we examined 5,731 YOY Gizzard Shad and found no Asian carp YOY. Three of the actions were triggered by three consecutive positive eDNA detections for Bighead and/or Silver Carp in the same location.

A threshold framework for response actions with conventional gears and rotenone was developed before the 2011 field season. The framework was released in the 2011 MRRP and included three thresholds for response based on positive eDNA detections and captured or observed Asian carp and three levels of response actions beginning with a conventional gear response and terminating in a rotenone action. The MRRWG changed the eDNA threshold for response from positive detections for either species in two consecutive eDNA sampling events from a given location to three consecutive eDNA sampling events from a given location. The increase was due to uncertainty in the meaning of positive eDNA detections for Asian carp (e.g., do positive detections represent live or dead fish, one or many fish, or sources other than live fish, such as DNA from barges, piscivorous birds, or the metropolitan sewer system). The absence of Bighead and Silver Carp in 2010 response actions also raised questions concerning the efficacy of eDNA as a response trigger, although it should be noted that eDNA sampling immediately prior to response actions in 2010 and 2011 always agreed with results of conventional gear and rotenone sampling (i.e., water samples collected immediately before response actions produced no positives for Bighead or Silver Carp DNA). Results of eDNA sampling immediately prior to response actions in 2012 did not agree with results of conventional gear on two of three eDNA triggered response occasions (See Strategy for eDNA Monitoring). Thus, the question was raised again concerning the use of eDNA monitoring as a trigger for response actions.

The MRRWG has used rotenone twice in the CAWS as a tool for electrical barrier maintenance and Asian carp rapid response. Both of these events used large quantities of rotenone, and quantities needed for future rapid response actions are unknown at this time. In addition, the raw

materials used to manufacture rotenone are not always available on short notice. Due to concerns over the short-term availability of the large quantities of rotenone potentially needed for a rapid response action, the US Fish and Wildlife Service was asked to purchase and store rotenone. The Service purchased approximately 2,000 gallons of rotenone, and is storing it at the Lost Mound Unit of the Savanna District, Upper Mississippi River National Wildlife and Fish Refuge. The Illinois Department of Natural Resources also has donated, and the Service is storing, more than 700 gallons of sodium permanganate left over from the previous rapid response event.

Recommendations: We recommend continued vigilance in removing any Bighead or Silver Carp from the CAWS upstream of Lockport Lock and Dam. Rapid response actions with conventional gears and rotenone represent the best available tools for localized removal or eradication of Asian carp to prevent them from becoming established in the CAWS or Lake Michigan. We recommend continued assessment of experimental gears during response actions as an alternative means for capturing Asian carp. We propose a new framework be used to guide management decisions on rapid response actions in the CAWS where eDNA is no longer a response trigger while establishing the capability to conduct targeted response actions at selected locations. Continuing to maintain a sufficient supply of rotenone and sodium permanganate in nearby storage is recommended for rapid response with rotenone when such an action is supported by the MRRWG and action agency representatives.

Project Highlights:

- Completed five response actions with conventional and experimental gears in the CAWS upstream of the electric barrier system during 2012. Three of the actions were triggered by three consecutive positive detections for Asian carp eDNA in the same location.
- Estimated 1,630 person-hours were spent to complete 59 hours of electrofishing, set 18.4 miles of trammel/gill net, make three 800-yard long commercial seine hauls, and deploy two tandem trap nets, 10 hoop nets and two Great Lake pound nets equal to 30.3 net-days of effort.
- Across all response actions and gears, sampled over 29,818 fish representing 53 species and 2 hybrid groups.
- No Bighead or Silver Carp were captured or observed during response actions.
- US Fish and Wildlife Service is maintaining in storage a supply of rotenone and sodium permanganate to facilitate a rotenone response action should conditions warrant such an action in the future.
- Recommend continued vigilance in removing any Bighead or Silver Carp from the CAWS upstream of Lockport Lock and Dam and development of a new threshold framework to guide decisions on rapid response actions in the CAWS. Also recommend establishing the capability to conduct targeted response actions at selected locations in the CAWS outside the threshold framework when information gained from such actions may benefit monitoring protocols, research efforts, or Asian carp removal and control efforts.

Table 1. Summary effort and catch data for Asian carp rapid response actions in the CAWS upstream of the Dispersal Barrier, 12 June – 31 October 2012.

Operation (date) and Gear	Estimated person-hours	Sample Effort		Catch				
		Samples (*N*)	Total effort	All fish (*N*)	Species (*N*)	Hybrids (*N*)	Bighead carp (*N*)	Silver carp (*N*)
2012 Response Actions								
Lake Calumet (12-13 June)								
Electrofishing	110	33 transects	8.25 hours	2,381	33	2	0	0
Trammel/gill nets	120	39 net sets	5.2 miles	732	7	1	0	0
Lake Calumet (11-13 July)								
Electrofishing	60	32 transects	8 hours	1,223	25	2	0	0
Trammel/gill nets		36 net sets	4.9 miles	341	7	1	0	0
Commercial seine		3 hauls	1.4 miles	3,524	18	0	0	0
Tandem trap nets	540	2 sets	7.6 net-days	113	11	0	0	0
Hoop nets		10 sets	19.1 net-days	10	5	1	0	0
Trap/pound nets		4 sets	3.6 net-days	213	12	0	0	0
North Shore Channel (16-17 October)								
Electrofishing	260	100 transects	22 hours	13,223	37	1	0	0
Trammel/gill nets	120	46 net sets	1.6 miles	53	6	1	0	0
Chicago River (18-19 October)								
Electrofishing	195	55 transects	13.2 hours	3,168	27	1	0	0
Trammel/gill nets	90	33 net sets	1.8 miles	83	3	0	0	0
Lake Calumet (30-31 October)								
Electrofishing	60	30 transects	7.5 hours	4,464	32	1	0	0
Trammel/gill nets	75	26 net sets	4.9 miles	290	9	0	0	0

Table 2. Total number of fish captured with electrofishing, trammel/gill nets, commercial seines, tandem trap nets, hoop nets and Great Lake pound nets during Lake Calumet, North Shore Channel and Chicago River rapid response actions, 12 June – 31 October.

	Response Action															
	Lake Calumet 12-13 June		Lake Calumet 11-13 July							North Shore Channel 16-17 October		Chicago River 18-19 October		Lake Calumet 30-31 October		
Species	Electro-fishing	Trammel/ Gill nets	Electro-fishing	Trammel /Gill nets	Deep water gill nets	Commercial seine	Tandem trap nets	Hoop nets	Pound nets	Electro-fishing	Trammel /Gill nets	Electro-fishing	Trammel /Gill nets	Electro-fishing	Trammel /Gill nets	All actions
Gizzard shad > 6 in.	295	1	89		1	1,084	3		60	3,201	3	1,092		82	3	5,914
Gizzard shad < 6 in.	453		379			2				1,704		1,094		2,099		5,731
Bluegill	197		103			1	1			3,592		322		260		4,476
Common carp	341	545	200	298	2	1,691	26	3	26	232	42	114	80	8	52	3,660
Bluntnose minnow	327		21							759		21		849		1,977
Gizzard shad (not specified)										1,537						1,537
Largemouth bass	172		116			7	2			406		103		245		1,051
Pumpkinseed	213		107				44			328		100		47		839
Channel catfish	31	2	13	17	2	617	14	1	12	31	1	4	2		4	751
Golden shiner	1		10							422		78		2		513
Spotfin shiner	5		10							437		23		2		477
Banded killifish	27		9											356		392
Brook silverside	38		8									29		214		289
Freshwater drum	12	74	16	6	9	65			30						49	261
Bullhead minnow	12									47				115		174
Black buffalo	1			2	1	5		1	8						136	154
Green sunfish	2		2							110		33		5		152
Yellow perch	20		31							17				52		120
Blackstripe topminnow										119						119
Emerald shiner	22		28							38		13		16		117
White perch	94		5			3	2		5			5		1		115
Bigmouth buffalo		75		1		3		1						4	3	87
White bass	8		3			22	10		35							78
Smallmouth buffalo		33	1			3			5	2	1				23	68
Fathead minnow	1									13				48		62
White sucker							5		1	52		1		1		60
Threadfin shad										2		48		4		54
Round goby	33									4		3		9		49
Black crappie	2								1	45						48
Orangespotted sunfish	17		5							23				2		47
Mosquitofish										2		44				46
Quillback	1					1	3	3	29						9	46
Alewife	10									33				1		44
Smallmouth bass	13		15			4				1		7		2		42

Table 2. Continued.

	Response Action															
	Lake Calumet 12-13 June		Lake Calumet 11-13 July							North Shore Channel 16-17 October		Chicago River 18-19 October		Lake Calumet 30-31 October		
Species	Electro-fishing	Trammel/ Gill nets	Electro-fishing	Trammel /Gill nets	Deep water gill nets	Commercial seine	Tandem trap nets	Hoop nets	Pound nets	Electro-fishing	Trammel /Gill nets	Electro-fishing	Trammel /Gill nets	Electro-fishing	Trammel /Gill nets	All actions
Brown bullhead	5		32							2				1		40
Yellow bullhead	2		6			4	3			11		3		5		34
Chinook salmon										4	1	3		13	11	32
Rock bass	5		1							6		6		11		29
Spottail shiner	3									16		5		4		28
Goldfish	1		2			9				5		4		2		23
Sunfish hybrid	6		1							13		4		1		25
Black bullhead	6		9							1				1		17
Carp x goldfish hybrid	2	1	1	1				1			4					10
Oriental weatherfish										1		4				5
White crappie	3					2										5
Rainbow trout												2		1		3
Coho salmon										1	1					2
Creek chub										2						2
Flathead catfish						1			1							2
Grass carp		1		1												2
Walleye												2				2
Warmouth										2						2
Brown trout													1			1
Central mudminnow														1		1
Northern pike												1				1
Silver chub										1						1
Skipjack herring										1						1
All species	2,381	732	1,223	326	15	3,524	113	10	213	13,223	53	3,168	83	4,464	290	29,818
Species (*N*)	33	7	25	6	5	18	11	5	12	37	6	27	3	32	9	53
Hybrids (*N*)	2	1	2	1	0	0	0	1	0	1	1	1	0	1	0	2

Barrier Maintenance Fish Suppression

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

and

Samuel Finney and Jeffrey G. Stewart;
US Fish and Wildlife Service – Carterville Fish and Wildlife Conservation Office

and

Jackson Gross, James Dunker, and Douglass Yeskis;
Northern Rocky Mountain and Illinois Water science centers

and

David C. Glover and James E. Garvey;
Southern Illinois University Carbondale

Participating Agencies: Illinois Department of Natural Resources (lead); US Fish and Wildlife Service, US Army Corps of Engineers – Chicago District, Southern Illinois University Carbondale, 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 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 800 feet 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 220 feet downstream of Barrier 2B. Barrier 2A and 2B can operate at parameters shown to repel juvenile and adult fish >5.4 inches long at a setting of 2.0 volts per inch or fish >2.5 inches long at a setting of 2.3 volts per inch (Holliman 2011). The higher setting has been in use since December 2011.

Barriers 2A and 2B must be shut down for maintenance approximately every 6 months and IDNR supports 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 the December 2009 rotenone operation completed in support of Barrier 2A maintenance and before Barrier 2B was constructed. Full function of Barriers 2A and 2B allows for fish suppression actions smaller in scope as one barrier can remain on while the other is 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 and can be energized to normal operating level in a matter of minutes. The threat of Asian carp invasion from downstream waters calls for a need to clear fish from the 220-foot length of canal between Barrier 2A and 2B each time

Barrier 2B is shut down for scheduled maintenance. The suppression plan requires Barrier 2A 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. Clearing will be considered successful when no fish larger than 300 mm (12 inches) are observed between the barriers. A cut-off of 300 mm was implemented to target sub-adult and adult Asian carp and exclude young-of-year fish. Excluding young-of-year Asian carp from the assessment was derived from prior 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 over the past decade.

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

1) Eliminate all fish >12 inches 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 (canal drawdown to increase current velocity , surface and underwater noise, surface DC electrofishing, deep-water AC electrofishing, surface to bottom gill nets, and water guns) 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, side-scan sonar, and DIDSON imaging sonar). Success is defined as no fish >12 inches long in the between-barrier area, as determined with remote sensing gear.

Methods:

Fish Clearing Operation – Sampling occurred in the electric barrier system between Barrier 1 and 2A on three occasions in 2012. Clearing was considered successful when no fish larger than 300 mm (12 inches) were observed between the barriers.

May 12, 2012 – We used split-beam hydroacoustics, side-scan SONAR, and DIDSON imaging surveys between Barrier 1 and 2A to enumerate and locate fish >12 inches in length prior to and after clearing actions. A canal drawdown was implemented to increase water flow to 3,500 cfs over the electric barriers during water gun operations in an effort to flush stunned fish from the barrier area. Fish were driven downstream from Barrier 1 with 1 cu. in. and 120 cu. in. hydraulic piston pneumatic water guns.

June 21,2012 and November 14, 2012 – We used split-beam hydroacoustics, side-scan SONAR and DIDSON imaging surveys of the area between Barrier 1 and 2A prior to clearing to enumerate and locate fish >12 inches in length. Hydroacoustics, side-scan sonar and DIDSON imaging were also used to locate fish during electrofishing and netting operations to provide updated fish locations and observe fish response to sampling gears. Water flow was reduced over the barrier during the operation to create more favorable conditions for gill netting. The gill net was 300 feet long x 30 feet deep with bar mesh ranging from 2.75-3.5 inches. The net was set stationary 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 electrofishing boats were used to target and stun or drive fish towards the stationary gill net that was in place across the canal. We used a pulsed-DC surface water electrofishing boat and an AC deep water

electrofishing boat equipped with extendable electrodes that can stun fish located deeper in the water column to capture fish. The DIDSON imaging boat communicated fish locations to the electrofishing boat operators. Surveys were then conducted with split beam hydroacoustics, side scan sonar, and DIDSON imaging to evaluate the success of the fish clearing action.

Results and Discussion: An estimated 420 person-hours were spent sampling in the dispersal barrier during barrier maintenance events in 2012 (Table 1). The May 12 water gun clearing effort was considered unsuccessful due to sensing surveys that indicated only one fish >12 inches was cleared from the barrier and 7 more fish >12 inches remained. As a result, the June barrier maintenance event was executed using surface pulsed-DC electrofishing, deep-water AC electrofishing and 30 foot deep gill nets. Pulsed-DC electrofishing and deep-water AC electrofishing were used to drive fish to the 30 foot gill net set across the canal; no electrofishing data was collected. The November 14th operation included two electrofishing boats (one surface and one deep-water shocker) and a stationary surface-to-bottom gill net which caught five common carp >12 inches long. Numerous small-bodied fish were sampled between the barriers by electrofishing, including Gizzard Shad, Pumpkinseed, Bluegill, Green Sunfish, Mosquitofish, Round Goby, Bluntnose Minnow, and State-threatened Banded Killifish (Table 2). Two fish targets, estimated to be 13-15 inches long, were identified between the barriers in the final remote sensing surveys. The targets were thought to be adult Gizzard Shad that were observed during an earlier electrofishing run, but not captured. The barrier zone was considered Bighead and Silver Carp free, requiring no further clearing activities until the next maintenance cycle. Effort for each gear across all three maintenance events was 8.0 hours of surface pulsed-DC electrofishing and deep-water AC electrofishing, 2.25 hours of water gun operations and 6.0 hours of hydroacoustic transects (Table 1). Across all gears and all events, we sampled a total of 100 fish representing 12 species with no hybrids collected (Table 2). Gizzard Shad were the most abundant species accounting for 61% of the total catch (Table 2). Other abundant species in the catch were Common Carp, Bluegill, Pumpkinseed, and Green Sunfish which made up 33% of the total catch (Table 2). No Bighead or Silver Carp were captured or observed during sampling.

Project Highlights:

- Multiple agencies and stakeholders cooperated in successfully removing fish between Barrier 2A and 2B for necessary barrier maintenance on 2 separate operations (June 21st and November 14th).
- A total of 100 fish were removed with 13 fish > 12 inches in length by hydroguns, surface and deep-water electrofishing and 30 foot deep gill netting.
- A total of 6 hours of split-beam hydroacoustics, side-scan SONAR, and DIDSON imaging sonar where used to assess the success of the fish clearing operation by surveying the area in and near the electric barrier system.
- No Asian carp were captured or observed during fish suppression operations.
- Recommend continued use of hydroacoustics to survey in between 2A and 2B for fish > 12 inches and sample using surface and deep-water electro-fishing alongside 30 foot deep gill nets to effectively remove all threats in the electric barrier system.

Table 1. Summary effort and catches for Lockport Pool Barrier Maintenance fish sampling events, 12 May, 21 June and 14 November 2012.

		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*)
May Sampling	100							
Hydroguns		1 transect	2.25 hours	--	--	--	--	--
Hydroacoustics		3 transects	1.5 hours	--	--	--	--	--
June Sampling	160							
DC electrofishing		4 transects	4.0 hours	0	0	0	0	0
Surface to bottom gill nets		2 net sets	200 yards	7	1	0	0	0
Hydroacoustics		5 transects	2.5 hours	--	--	--	--	--
November Sampling	160							
DC electrofishing		4 transects	4.0 hours	88	10	0	0	0
Surface to bottom gill nets		2 net sets	200 yards	5	1	0	0	0
Hydroacoustics		4 transects	2.0 hours	--	--	--	--	--

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 2012.

	June 21 Sampling Gear	November 14 Sampling Gear		
Species	Surface to Bottom Gill Nets	DC electro-fishing	Surface to Bottom Gill Nets	All gears
Gizzard Shad <6 in.		61		61
Banded Killifish		2		2
Bluntnose Minnow		1		1
Common Carp	7	5	5	17
Bluegill		5		5
Green Sunfish		2		2
Mosquitofish		1		1
Rainbow Trout		1		1
Round Goby		1		1
Pumpkinseed		9		9
All species	7	88	5	100
Species (*N*)	1	10	1	10
Hybrids (*N*)	0	0	0	0

Barrier Defense Asian Carp Removal Project

David Wyffels, Mike McClelland, Victor Santucci, Kevin Irons, Tristan Widloe, Brennan Caputo, Blake Ruebush, John Zeigler; Matt O'Hara
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 numbers of Asian carp in the upper Illinois and lower Des Plaines rivers downstream of the electric barrier system. By decreasing Asian carp numbers, we anticipate decreased migration pressure towards the electric barrier system 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 2012 using ten contracted commercial fishing crews to remove Asian carp with large mesh (3.0 - 4.0 inch) 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 barrier system. 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 barrier system, 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 barrier system, 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. Contracted commercial fishing took place from June-September 2010, April-December 2011, and March-December 2012. Five commercial fishing crews per week with assisting IDNR biologists fished Tuesday through Friday 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 – 4.0) 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 in 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 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 and weighed in grams 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 netting for Asian carp during barrier defense removal efforts. A total of 643.3 miles of net has been deployed in the upper Illinois Waterway to date (Table 1). The combined catch of Asian carp (Bighead, Silver, and Grass Carp) was 6,073 fish during 2010, 41,054 fish during 2011, and 45,501 fish during 2012 (Table 1). Total biomass of Asian carp caught and removed from 2010-2012 was 1,397,440 pounds or 698.72 tons (Table 1). Bighead Carp, Silver Carp, and Grass Carp accounted for 63.1%, 36.7%, and 0.2% of the total biomass harvested since 2010 respectively.

Bighead Carp accounted for 82.0% of all Asian carp harvested in 2010, 56.3% in 2011 and 39.4% in 2012. Silver Carp accounted for 17.7% of all Asian carp harvested in 2010, 43.4% in 2011 and 63.0% in 2012. Grass Carp accounted for 0.3% of all Asian carp harvested in 2010, 0.4% in 2011 and 0.6 % in 2012. The decline in percentage of catch of Bighead Carp since 2010 coincided with a greater proportion of Silver Carp in the catch from Starved Rock Pool. Starved Rock Pool Silver Carp catches accounted for 26.1% of all Asian carp harvested in 2011 and increased to 43.7% in 2012. The total harvest of Asian carp 2010-2012 consisted of 48.2 % Bighead Carp, 51.3% Silver Carp, and 0.5% Grass Carp. The annual catch per unit effort (CPUE *N*/1,000 yards of net) of all pools combined was similar in 2012 (87.6 Asian carp per 1,000 yards of net) to 2011 (86.9 Asian carp per 1,000 yards of net). A trend line fitted to monthly CPUE for all pool combined shows a decline in monthly CPUE since April 2011 (Figure 1).

Catch of Asian Carp within Pools

Dresden Island Pool:

The Dresden Pool was fished late March through early December 2012, with the exception of May and June, which were not sampled as part of the Barrier Defense removal project (See Fixed Site Monitoring Downstream of the Dispersal Barrier Report). A total of 76 Bighead Carp, 13 Silver Carp, and 1 Grass Carp were harvested in 2012 from Dresden Island Pool (Table 1). Bighead Carp dominated the harvest numerically, accounting for 83% of the harvest in Dresden

Island Pool since 2010. Silver Carp accounted for 9.5% of the harvest since 2010. The CPUE of Asian carp continues to be low and declined in the Dresden Island Pool from 4.9 Asian carp per 1,000 yards of net in 2011 to 2.6 Asian carp per 1,000 yards of net in 2012. Monthly CPUE for Asian carp captured in the Dresden pool from 2011 -2012 can be found in Figure 2.

Marseilles Pool:

The Marseilles pool was fished from late March through early December in 2012. A total of 12,126 Bighead Carp, 8,744 Silver Carp, and 75 Grass Carp were harvested in 2012 (Table 1). Similar to 2010 and 2011, the catch in 2012 was greatest for Bighead Carp (57.9%). Most of the Asian carp harvested during 2012 in the Marseilles Pool came from the Hanson Material Services (HMS)-West Pit (N = 11,345). The HMS-West Pit also had the highest Asian carp CPUE for 2012 (69.9 Asian carp per 1,000 yards of net). The high density of Asian carp in HMS-West Pit was also confirmed by Hydroacoustic surveys done by Sothern Illinois University Carbondale (SIUC) during 2012 (See Monitoring Asian Carp Population Metrics and Control Efforts Report). The HMS-East Pit had the second highest number of Asian carp harvested (N = 7,367) accounting for 32.7% of the total catch (53.8 Asian carp per 1,000 yards of net). All other areas (e.g. Peacock Slough, off channel sets, and other small back water areas) accounted for 10.7% of the total catch (N = 2,233). The annual CPUE of Asian carp in the Marseilles Pool fell from 72.1 Asian carp per 1,000 yards of net in 2011 to 56 Asian carp per 1,000 yards of net in 2012. Monthly CPUE for Asian carp captured in the Marseilles pool from 2011-2012 can be found in Figure 2.

Starved Rock Pool:

Starved Rock Pool was fished for the first time in 2011 and continued in 2012. A total of 24,466 Asian carp were harvested in 2012, an increase of 10,640 Asian carp from 2011(Table 1). Silver Carp were the numerically dominate species harvested in 2012 (81.2%) and 2011 (Table 1). Annual CPUE of Asian carp increased from 174.4 Asian carp per 1,000 yards in 2011 to 221.9 Asian carp per 1,000 yards of net in 2012. This increase is likely a result of increased effort in high density areas like Sheehan Island in 2012. Sheehan Island was fished for only the last three months of the 2011 year which resulted CPUE of 365 Asian carp per 1,000 yards of net for those months. These high CPUE continued in March 2012 (983.5 Asian carp per 1,000 yards of net), but declined over the 2012 harvest year to a final CPUE of 52.4 Asian carp per 1,000 yards of net in October. As CPUE declined in the Sheehan Island area, the confluence of the Fox River and the Heritage Marina were identified as areas with high densities of Asian carp through hydroacoustic surveys done by SIUC. The Fox River confluence was fished for the last three months of 2012 and had a CPUE of 483.0 Asian carp per 1,000 yards of net. Monthly CPUE for Asian carp captured in the Starved Rock pool from 2011-2012 can be found in Figure 2.

Catch of By-Catch Species

A total of 58,391 fish representing 31 species and 2 hybrid groups were caught in trammel and gill nets during the 2012 Asian carp removal effort (Table 2). Asian carp (Bighead, Silver, and Grass Carp) made up 77.4% of the catch and the three Buffalo species (Bigmouth Buffalo, Smallmouth Buffalo, and Black Buffalo) and Common Carp made up an additional 19.5% of the total catch. These percentages are very similar to 2011 in which Bighead, Silver and Grass Carp made up 77.6% of the catch and three Buffalo spp. with Common Carp made up an additional 19.8%. A total of 537 fish from 12 species and 1 hybrid species made up the total sport fish captured in 2012. Sport fish represented 0.9 % of the total catch in 2012, this is similar to 2011when sport fish represented 1.1%. Flathead and Channel Catfish were again the numerically dominate sport fish captured in 2012 accounting for 81.2 % of the sport fish captured.

Recommendations: We recommend continuing the Asian carp removal program in the upper Illinois Waterway to reduce Asian carp abundance at and near the detectable population front and prevent further upstream movement by populations toward the electric barrier system and Lake Michigan. Using 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 electric barrier system. 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 643.3 miles of net in the upper Illinois Waterway from 2010- 2012.
- A total of 44,658 Bighead Carp, 47,474 Silver Carp, and 496 Grass Carp were removed by contracted netting. The total weight of Asian carp removed was 698.72 tons (62.41 tons in 2010, 351.78 tons in 2011 and 284.53 tons in 2012).
- 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 barrier system and Lake Michigan.

Table 1: Gill and trammel netting effort and harvest of Asian Carps from Dresden, Marseilles and Starved Rock pools during 2010-2012 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
2010-2012										
Dresden Island	268	36.4	235	27	22	284	2.31	0.21	0.20	2.72
Marseilles	2,586	500.2	37,101	16,842	109	54,052	392.88	108.53	0.18	501.59
Starved Rock	349	106.7	7,322	30,605	365	38,292	46.03	147.55	0.83	194.41
All pools	3,203	643.3	44,658	47,474	496	92,628	441.22	256.29	1.21	698.72

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 and 2012. All Species other than Asian Carp and Common Carp were returned to the River immediately after capture.

	2011		2012	
Species	Number Captured	Percent %	Number Captured	Percent %
Bighead Carp	23117	43.68%	16560	28.36%
Silver Carp	17776	33.59%	28632	49.03%
Smallmouth Buffalo	3853	7.28%	3749	6.42%
Bigmouth Buffalo	3850	7.27%	5043	8.64%
Common Carp	2574	4.86%	2386	4.09%
Freshwater Drum	573	1.08%	689	1.18%
Flathead Catfish	313	0.59%	299	0.51%
Channel Catfish	201	0.38%	137	0.23%
Black Buffalo	188	0.36%	262	0.45%
Grass Carp	171	0.32%	299	0.51%
Paddlefish	78	0.15%	51	0.09%
River Carpsucker	61	0.12%	26	0.04%
Quilback	37	0.07%	46	0.08%
Largemouth Bass	28	0.05%	22	0.04%
Sauger	19	0.04%	31	0.05%
Shortnose Gar	16	0.03%	37	0.06%
White Bass	13	0.02%	11	0.02%
Longnose Gar	11	0.02%	25	0.04%
Walleye	9	0.02%	12	0.02%
Skipjack Herring	9	0.02%	14	0.02%
Blue Catfish	8	0.02%	7	0.01%
Gizzard Shad	6	0.01%	22	0.04%
Yellow Bass	3	0.01%	5	0.01%
Striped Hybrid Bass	2	> 0.01%	7	0.01%
Spotted Gar	1	> 0.01%		
White Crappie	1	> 0.01%	2	> 0.01%
Bluegill			1	> 0.01%
Black Crappie	1	> 0.01%	1	> 0.01%
Shorthead Redhorse		> 0.01%	1	> 0.01%
Golden Redhorse			2	> 0.01%
River Redhorse	1	> 0.01%		
Rock Bass			1	> 0.01%
Muskellunge	1	> 0.01%		
Northern Pike	1	> 0.01%	1	> 0.01%
Common Carp x Goldfish Hybrid	1	> 0.01%	4	0.01%
Mooneye			6	0.01%
Goldeye	1	> 0.01%		
Total all Species	52924		58391	

Figure 1: Monthly Catch per unit effort (CPUE; Asian Carp/1,000 yards of gill/trammel net) for all pools combined in 2011 and 2012. No barrier defense effort was completed for all pools for the months of January-February 2012.

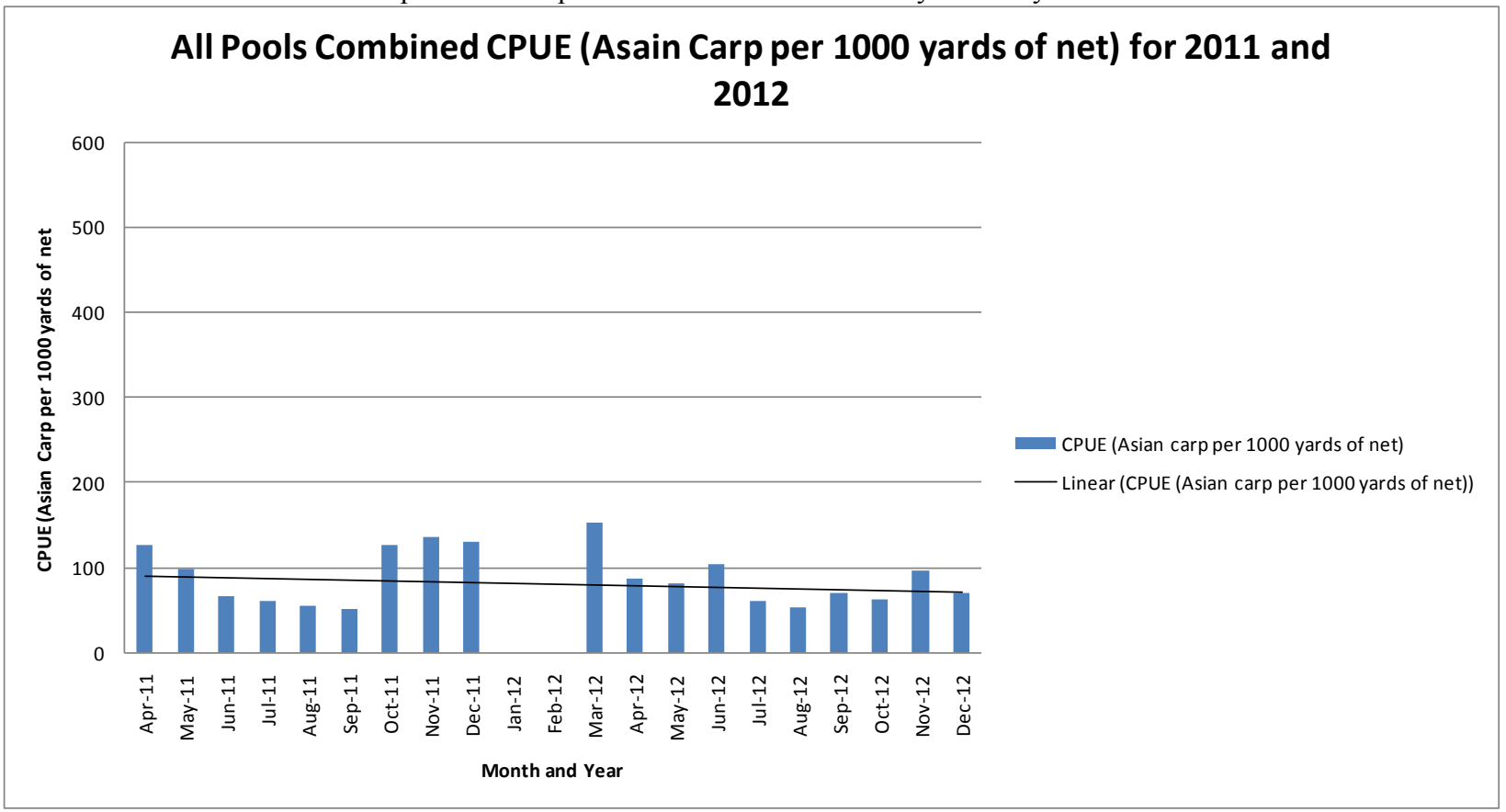
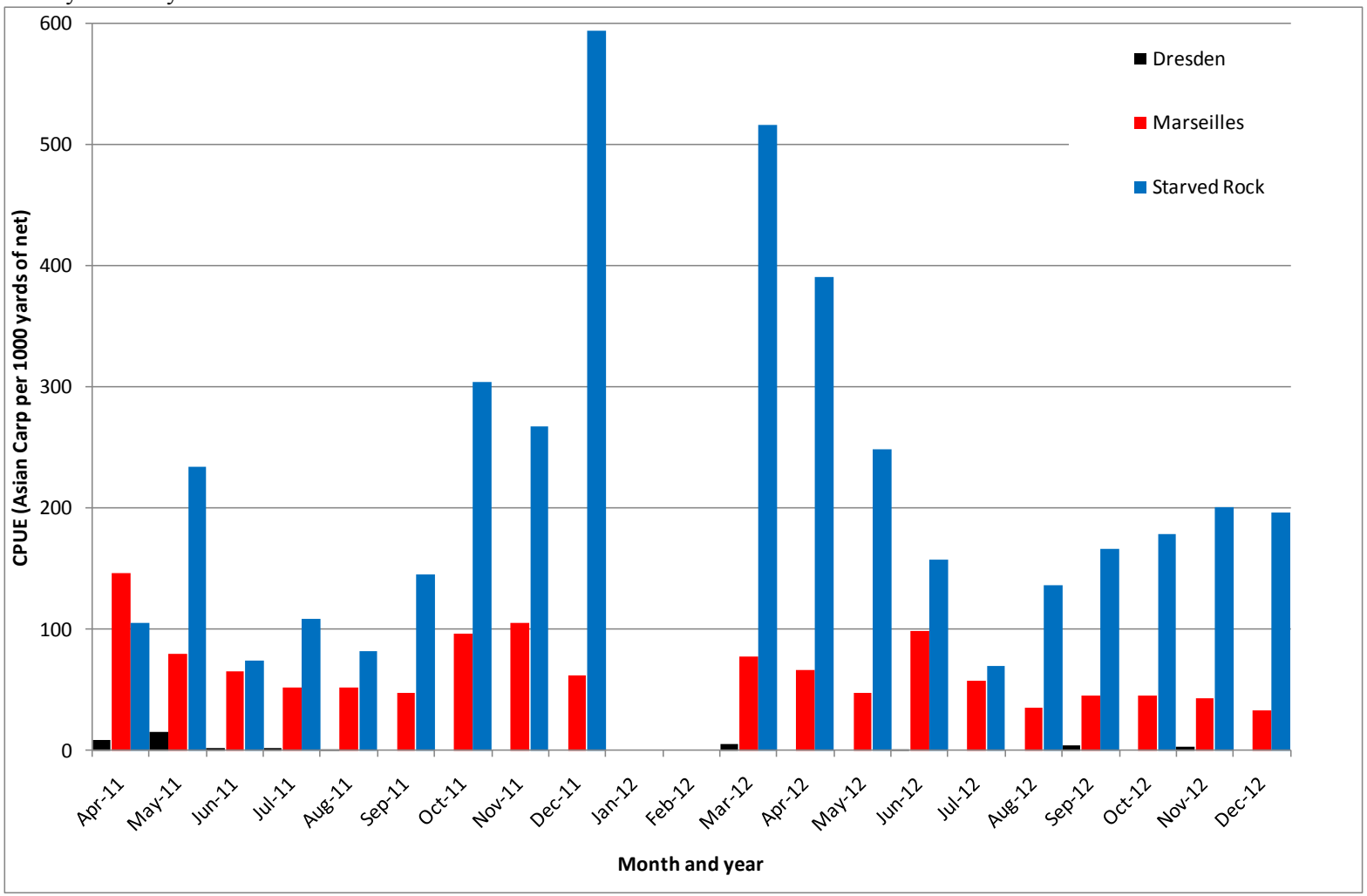


Figure 2: Monthly Catch per unit effort (CPUE; Asian Carp/1,000 yards of gill/trammel net) for Dresden, Marseilles and Starved Rock Pools in 2011 and 2012. No barrier defense effort was completed for the Dresden Island Pool for the months of November-December 2011, January-February 2012, May 2012, and July 2012. No barrier defense effort was completed for the Marseilles and Starved Rock Pools for the months of January-February 2012.



Monitoring Asian Carp Population Metrics and Control Efforts: Preventing Upstream Movement in the Illinois River

James E. Garvey, David C. Glover, Marybeth K. Brey, Wesley Bouska, Greg Whitledge; Southern Illinois University at Carbondale.

Participating agencies: Southern Illinois University at Carbondale (lead); Illinois Department of Natural Resources, US Army Corps of Engineers - Chicago District, US Fish and Wildlife Service - Carterville, Illinois Natural History Survey (field support); US Coast Guard (waterway closures); Metropolitan Water Reclamation District of Greater Chicago (waterway flow management and access); Western Illinois University (genetic testing, field 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

Introduction: Asian carp of the genus *Hypophthalmichthys* became abundant in the Illinois River in the early 2000s (Chick and Pegg 2001). As of 2013, they have invaded Dresden Pool and have reached apparently high densities in Marseilles Pool (about 80 miles downstream of Lake Michigan). Although present, they do not appear to have reproduced in the upper river. These two reaches are below the electric barrier system emplaced in the Chicago Sanitary and Ship Canal (CSSC). If Asian carp do move upstream and the electric barrier system fails, these fishes threaten to invade the Chicago Area Waterway System (CAWS) and Lake Michigan. Populations of Asian carp have become established with apparent reproduction occurring in the river below the Starved Rock Lock and Dam (L&D), which is comprised of the Peoria, LaGrange, and Alton reaches. Asian carp are a clear nuisance in these areas and likely negatively affect the local ecosystems and economies.

The goal of this research is to evaluate the impact of two potentially complementary control efforts that are occurring in the Illinois River. Currently, removal by fishing is the only efficacious control method. In reaches above Starved Rock L&D, contracted fishing is occurring to reduce the numbers of adult Asian carp that may swim to the electric barrier system and challenge it. These fishes also may build populations in Dresden and Lockport reaches. In reaches below Starved Rock L&D, privately supported commercial fishing occurs for Asian carp, although the effort varies depending on market demand, fish condition, fish abundance, and river conditions.

Asian carp populations that are in proximity to the electric barrier system within the CSSC likely originate from the lower river below Starved Rock L&D. The highest density of Asian carp in this area is in a quarry (Hanson Material Service Corporation pits) adjacent to the river in Marseilles Pool. Our research group quantified Asian carp densities in this area during 2011, finding that densities declined from 300,000 to 198,000 fish, likely as a function of contracted fishing and emigration. Research in 2012 was aimed at determining the relative impact of

fishing, emigration, and immigration on Asian carp densities in this important location near the barrier.

Methods: In 2011, we conducted the first comprehensive density and biomass estimate of the Illinois River fish assemblage using a combination of trammel netting, electrofishing, and split-beam hydroacoustics. This allowed us to set a baseline by which changes in Asian carp density and assemblage structure could be compared to control efforts and environmental conditions. Hydroacoustics, which allows us to generate a density and biomass estimate for the river, was restricted to the main channel. Greater than 2,100 miles of transects were completed. Density of Asian carp below Starved Rock L&D to the Mississippi River confluence was conservatively estimated at 743,000 individuals, comprising 1,400 tons. Asian carp dominated fish biomass, comprising more than 60% of the biomass. Our estimate was clearly conservative. Fish avoided the survey boat. The acoustics beam was only down-looking, missing shallow areas of the river such as side channels and off-channel areas. We considered this a learning experience and opportunity to improve our sampling techniques for 2012. Data collected during 2012 that are currently being processed will allow us to "correct" our 2011 estimates to reflect a more accurate density in the main channel.

Past research conducted by our group and others has established that Asian carp are capable of moving long distances, often during a very short time (> 200 miles/month). Key to any control effort that reduces risk of Asian carp breaching the electric barrier is an understanding of the immigration rates of Asian carp from downstream "sources". In 2011 we found that immigration of Asian carp into the Illinois River from the Mississippi River is triggered by flooding. Tagged carp moved as far north as Peoria Pool; about 25% were found moving back downstream. What factors influence whether an individual remains upstream or leaves is unknown. How fish interact with lock and dam structures throughout the river, particularly at Starved Rock L&D and structures upstream is not understood. These areas may serve as attractants downstream (e.g., high densities of Asian carp occur below Starved Rock L&D) but as barriers to upstream movement. Research in 2012 began to address these issues by assessing how fishing and environmental factors such as elevated discharge affect movement toward the CAWS.

For harvest or any control effort to suppress adults from moving upstream and for the contributing populations to shrink, a host of complex, interacting factors must come to play. A simple demographics model based on limited data for Asian carp was developed in 2011. This model suggested that control at all life stages was necessary to reduce the population in the Illinois River. Although a useful first step, a predictive model needs refinement. Foremost, how population characteristics (e.g., density, age structure, size structure, growth) affect movement of Asian carp toward the electric barrier system in the CSSC need to be quantified and incorporated in a spatially explicit fashion. Demographics data from 2011 showed that each pool of the Illinois River contains populations of Silver and Bighead Carp with unique demographic characteristics. Patterns of harvest vary across these reaches, leading to complex population responses. Recruitment of Asian carp is variable. Multiple years of poor recruitment coupled with harvest or other control measures may greatly reduce population density (e.g., Lohmeyer and Garvey 2009). Harvest and other control efforts that target the reproductively active individuals in the population (i.e., large females) may suppress population growth.

Results and Discussion: This report summarizes preliminary results of research conducted in 2012 in response to 2011 findings. Our approaches were complementary but broad. We assisted state and federal agencies in detecting potential Asian carp within the electric barrier system during routine maintenance and unexpected outages. Changes in Asian carp density on a daily basis as well as through the year were quantified at the "leading edge" of the upstream Silver and Bighead Carp populations in Marseilles Pool. We worked closely with contracted commercial fishermen in this area to evaluate the efficacy of harvest as a control method. In the river below Starved Rock L&D, we orchestrated harvest of three-million pounds of Asian carp in spring 2012. These fish were converted to fish meal to be used in feeding trials for fish and livestock. Density and demographic changes as well as potential modifications in upstream movement of telemetered Asian carp were quantified. Hydroacoustic surveys with down- and side-looking transducers were conducted across > 2,300 miles of river. Otolith microchemistry was used to determine origin of Asian carp. Unlike 2011, 2012 was a year of low discharge in the Illinois River. Our hydroacoustic assessment of the electric barrier system during clearing operations covered > 97% of the channel; fish identified with the gear were confirmed with other techniques. Harvest in 2012 removed > 19,000 Asian carp from the quarry adjacent to Marseilles Pool. Asian carp tagged in the area declined, but new Asian carp appeared to migrate into the area from the pool and perhaps from downstream reaches. Removal of Asian carp from the lower Illinois River was completed by June 2012, with a commensurate decline in catch rates of these fishes during standardized sampling. Sex ratio was skewed toward 17% more males than females. Movement of Asian carp among pools was limited in 2012, with downstream movement only occurring for 14 fish and with no apparent upstream movement. Microchemistry suggests that up to 61% of silver carp were produced in the Illinois River, whereas up to 97% of bighead carp originated there.

Population dynamics within the Illinois River and their implications are becoming clearer.

- Upstream movement of Asian carp is linked to flooding; limited discharge in the upper river may reduce the propensity for Asian carp to move en masse upstream toward the electric barrier system. This still needs to be further tested with telemetered fish across years of low and high discharge in the upper river.
- Large populations of Bighead and Silver Carp remain in Marseilles Pool of the upper river, associated with the adjacent quarry. Movement between the river channel and the quarry is frequent. Movement out of the quarry may be linked to contracted fishing occurring there.
- Contracted fishing in Marseilles reach does cause a decline in Asian carp. However, immigration of new fish is apparently high, offsetting this control effort.
- Asian carp in the upper river originate from the lower river or other rivers, particularly the Middle Mississippi River.
- Experimental harvest in the lower river (i.e., below Starved Rock L&D) coupled with poor recruitment reduced Asian carp densities. This should reduce the number of fish invading the upper river.
- Without economic incentives, commercial harvest in the lower river will remain low and control of Asian carp in the upper river (about Starved Rock L&D) will depend on the amount of government-sponsored fishing plus the reliability of the barrier system.

Project Highlights:

- Side-scan SONAR plus split-beam hydroacoustics was effective for evaluating the presence of fish > 12 inches in length in the electric barrier system. This monitoring system was deployed nine times in 2012.
- In Marseilles Pool, 279 Bighead Carp and 34 Silver Carp were tagged externally. Forty-nine percent of these fish were recaptured in 2012.
- Retrieval of tagged Asian carp showed us that contracted harvest caused 79% mortality in the quarry adjacent to Marseilles Pool.
- Frequency of the decline of tagged fish relative to untagged fish showed that immigration into the quarry offset removal of harvested fish during summer.
- Telemetry and acoustics showed that Asian carp in the quarry frequently move into the main channel and back.
- In spring 2012, 3,000,000 pounds of Asian carp were removed from Peoria, LaGrange, and Alton pools of the lower Illinois River.
- Sampling with electrofishing and trammel netting in late summer 2012 showed a decline in catch rates of Silver Carp by 33% in the lower river.
- Sex ratio of Asian carp shifted toward 17% more males than females.
- Analysis of age structure revealed that very little recruitment of Asian carp occurred in 2010 and perhaps 2011.
- Samples of fish putatively identified as "pure" Silver Carp, "pure" Bighead Carp, and hybrids were sent to Western Illinois University for analysis Pure Bighead and Silver Carp comprised 50.76% of genetic samples (hybrids=49.24%).
- Hydroacoustics combining down-looking and side-looking transects were completed in the river, comprising 2,306 miles of data collection. Analysis is ongoing. Habitat covered included 82.6% main channel, 5.2% backwater lakes, 5.1 % contiguous lakes, 4.9% side channels, 1.5% tributaries, and 0.4% harbors.
- A network of 30 stationary acoustic receivers for detecting tagged fish is now in place in the Illinois River (not including those receivers maintained by other research groups). Receivers were also placed in all lock chambers in early 2013.
- Three-hundred and seventy-two Asian carp were implanted with acoustic tags by fall 2012.
- Stationary receivers have made about 250,000 detections of tagged Asian carp by fall 2012. One-hundred fifty-seven Asian carp were located. At least seventeen Asian carp with transmitters were removed by harvest.
- In the upper river, no upstream movement of Asian carp was detected. Movement within pools was frequent.
- Elemental composition of Asian carp otoliths provided an environmental history. Up to 40% of Silver Carp in the Illinois River were produced outside the river, likely in the Middle Mississippi River. Conversely, only 3% of Bighead Carp were derived from outside the Illinois River.

Next Steps:

- Continue assisting IDNR and other agencies with assessing electric barrier system status during maintenance and unexpected outages.
- Work with USFWS to develop acoustic target strength relationships for Asian carp.
- Complete processing of hydroacoustics data from the upper and lower Illinois River in 2012 to provide a comprehensive density and biomass estimate of Asian carp. Use this estimate to "correct" the data collected in 2011.
- Continue to quantify effectiveness of the clearing efforts in the upper river.
- Assess patterns of migration in the Illinois River between the upper and lower river, focusing on the rates of immigration into the upper river, pathways of immigration (e.g., lock chambers or gates), harvest intensity, timing, and environmental conditions.
- Hold research summit with modelers to develop a comprehensive, spatially explicit model of population viability and dispersal in the Illinois River and other river reaches.

Telemetry Monitoring Plan

Matthew Shanks; US Army Corps of Engineers – Chicago District
Nicholas Barkowski; US Army Corps of Engineers – Chicago District

Participating Agencies: US Army Corps of Engineers (lead), US Fish and Wildlife Service, 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 ACRCC's Control Strategy Framework as one of the primary tools to assess the efficacy of the electric barrier system. The following outlines the sampling strategy for implementing a network of acoustic receivers supplemented by mobile surveillance to track the movement of Bighead Carp, Silver Carp, and associated surrogate fish species in the area around the electric barrier system in the CSSC. This network was installed and is maintained through a partnership between USACE and other participating agencies as part of the MRRWG's monitoring plan (MRRWG 2012).

The purpose of the telemetry program is to assess the effect and efficacy of the electric barrier system on tagged fish in the upstream and downstream environment of the CSSC and Illinois Waterways using ultrasonic telemetry. The goals and objectives are identified as:

Goal 1: Determine if fish are able to challenge and/or penetrate the electric barrier system (Barrier Efficacy)

- **Objective** Monitor the movements of tagged fish in the vicinity of the electric barrier system using receivers (N=8) placed immediately upstream, within, and immediately downstream of the electric barrier system, in addition to mobile tracking.
- **Objective** Determine if there is adequate detection coverage to effectively assess efficacy of the electric barrier system.

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

- **Objective** Monitor the movements of tagged fish at Dresden Island, Brandon Road, and Lockport Locks and Dams using stationary receivers (N=6) placed above and below each dam.

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

- **Objective** Describe existing conditions of habitat use and movement in the areas of the Upper IWW and tributaries where Asian carp have been captured and compare to areas in the CAWS where Asian carp are not currently present.
- **Objective** Integrate information between related studies (MWRD and Southern Illinois University).
- **Objective** Maintain existing acoustic network and rapidly expand to areas of interest in response to new information.

Methods: *Large Fish Study* – Based on MRRWG expert opinion, it was recommended that 200 tags be implanted for telemetry monitoring. At the end of the 2011 season there were approximately 152 large (V16) and 30 small (V6) tags implanted and released. Because increases in tags 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 for 2012 were specifically programmed to terminate their transmission after 60 days to reduce overlapping transmissions near the electric barrier system as fatalities occur and the tags/carcasses become stationary. Fish mortality and transmitter battery decay in the 2011 season also required additional tags to be implanted and released as replacements. A total of 36 large tags and 15 small tags were implanted into both Asian carp and surrogate species in 2012 which updated the total tags activated (excluding dead tags) within the system to 172 V16 and 15 V6 tags. Tagged surrogates have been released both above and below the electric barrier system; however, no tagged Asian carp were released above the Brandon Road Lock. It was determined that no Asian carp caught in Lockport pool would be tagged and returned as it might have resulted in the distortion of eDNA surveillance (see eDNA Monitoring Strategy). All fish were released at or near point of capture only after they were deemed viable and able to swim under their own power. Table 1 identifies the fishes tagged to date and their release point within the system.

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

Release Location	Species Implanted	Number of Fish Implanted
Chicago River above Barriers	Common Carp	20
Cal-Sag Channel above Barriers	Common Carp	18
	Freshwater Drum	2
Dispersal Barrier System	Green Sunfish	21
(Above and below active barrier)	Common Carp	1
(All small V6 tags)	Pumpkinseed	5
	White Sucker	5
	Skipjack Herring	1
	Largemouth Bass	9
	Smallmouth Bass	1
	Black Crappie	1
	Black Bullhead	1
CSSC Lockport Pool below Barriers	Common Carp	74
	Freshwater Drum	1
	Channel Catfish	1
Brandon Rd Pool	Common Carp	17
	Grass Carp	1
	Smallmouth Buffalo	1
Dresden Island Pool	Bighead Carp	17
	Smallmouth Buffalo	5
	Common Carp	5
Marseilles Pool	Bighead Carp	16
	Silver Carp	15
Total		**238**

Methods for tag implantation, stationary receiver deployment and downloads as well as mobile tracking were maintained from the previous year's efforts. Data retrieval occurred monthly throughout the season by mobile tracking techniques and downloading stationary receivers. A detailed description of methods is included in the MRRP Interim Summary Report (2012). Stationary receivers removed for winter in 2011 were redeployed in late March, 2012 with a few revisions to the layout of receiver positions within the study area. The receiver network was expanded into Marseilles Pool and increased detection capabilities at exit points within the system, such as tributaries and large backwaters. The study area was covered by 32 stationary receivers extending for approximately 77 river miles from the Bubbly Creek turning basin in Chicago 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 15 small fish captured from the Lockport pool at or within three miles downstream of the electric barrier system. In general, the total length of fish averaged 106 mm (4.2 in) with a minimum of 92 mm (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 MRRP Interim Summary Report (2012). Fish were released when they appeared to be in exceptional health 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 eight fish downstream. Fish movements were continuously tracked by stationary receivers and mobile tracking occurred in the area one week after release. This study is ongoing and an additional 15 fish are to be tagged and released in the spring of this year (2013).

Results and Discussion: The results discussed in this section will address the three goals of the study. As of November 2012, 5.5 million detections from 238 tagged fish, with a 66% detection rate, indicate that no tagged fish have crossed any of the electric barriers in the upstream direction.

Goal 1: Determine if fish approach and/or penetrate the Barrier

Adult Fish Testing: Seventy-six tagged fish greater than 15 inches have been released between the electric barrier system and the Lockport Lock and Dam. These fish are monitored within the vicinity of the electric barrier system by a network of eight VR4 receivers capable of producing positioning data for each tag as they are detected. Data presented here has been retrieved and analyzed for detection positions from June 2011 through May 2012. The remainder of 2012 data is still being processed for accurate positions. Throughout the period of analysis, 18 unique tags implanted into Common Carp approached the downstream edge of the electric barrier system for a total of 130 occurrences. No tags were determined to pass in either direction through the electric barrier system. The highest number of approaches to the electric barrier system occurred in summer months (Jun-Aug; n=63) and drastically reduced in frequency during the winter (Dec-Feb; n=1; Figure 1). Linear regression used to compare mean canal discharge rates to the total number of approaches to the electric barrier system each month indicated a significant positive

relationship (r^2=0.31, df=13, P=0.047). Monthly approaches were also compared against canal temperature and conductivity using linear regression (Figure 2). Temperature showed a significant positive relationship (r^2=0.49, df=13, P=0.01) indicating that tagged fish are more likely to approach the barriers with increasing temperatures. No significance was found between conductivity and fish behavior (r^2=0.06, df=13, P=0.42).

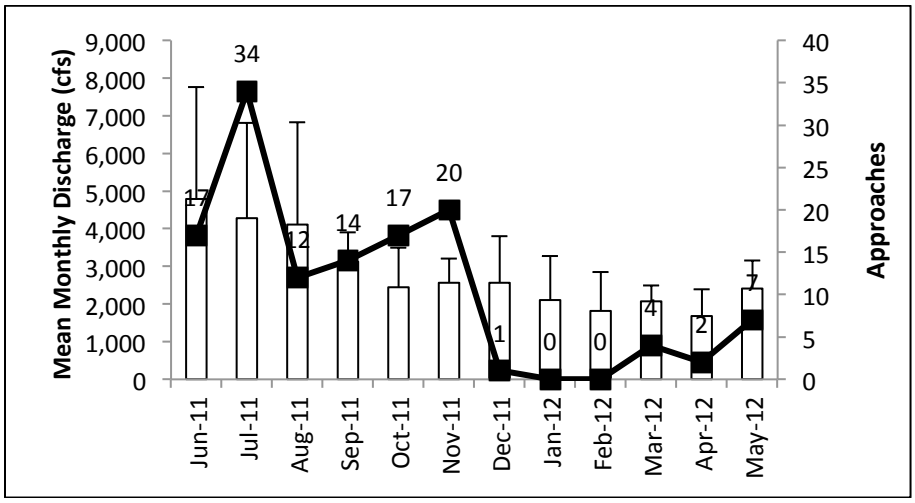


Figure 1: Total approaches to the dispersal barriers by tagged Common Carp and mean monthly discharge rates (cfs) with standard deviations.

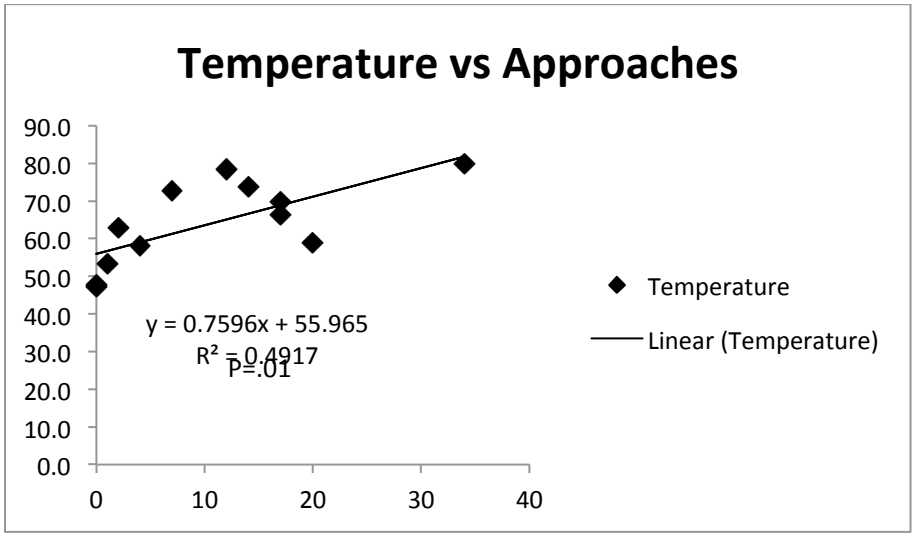


Figure 2: Total monthly approaches to the dispersal barriers by Common Carp regressed with mean monthly temperatures of the canal.

Small Fish Testing

Mobile tracking results of the small fish study indicated a majority of the tagged fish had left the vicinity of the electric barrier system at least one week after deployment. As tracking occurred using the VR100 receiver, only six unique tag IDs were detected near the electric barrier system indicating the remaining nine fish were no longer in the study area. Mobile tracking upstream of the electric barrier system did not indicate any upstream movement. All fish movements near the

electric barrier system were recorded by the Vemco Positioning System composed of eight VR4 receivers. Data is still being downloaded from the VR4 receivers and will be sent to Vemco for processing of the positioning data in the near future. This study is ongoing and includes an additional 15 small fish to be tagged and released in spring 2013. A full report on small fish behavior and barrier efficacy will be made available by late summer 2013.

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

In 2012 there were seven occurrences of tagged fish moving downstream and four occurrences of upstream movement between navigation pools by a total of nine individual fish. All inter-pool movement occurred across both the Lockport Lock and Dam (n=9) and the Dresden Island Lock and Dam (n=2). There was no movement detected between the Brandon Road and Dresden Island pools. Table 2 displays the total inter-pool passages since 2010.

Table 2: Total detections of tagged fish inter-pool movement from 2010 through November 2012.

Lock and Dam	**Total Passages**	**Direction of Travel**
Lockport	6	Upstream
Lockport	16	Downstream
Brandon Rd	0	Upstream
Brandon Rd	1	Downstream
Dresden Island	1	Upstream
Dresden Island	1	Downstream

The majority of inter-pool movement in 2012 occurred through the Lockport Lock in the downstream direction (n=6; 85.7%). Five of the six passages downstream through the Lockport Lock occurred on 19 June as the canal discharge peaked near 12,000 cubic feet per second (cfs). This same pattern of tagged fish moving from the Lockport to Brandon Road pool during a peak flow event was observed three times in 2011 as well. Further investigation into the exact operating conditions at Lockport Lock and Controlling works is recommended to determine the exact cause for the phenomenon. All other passages between pools within the study area, upstream or downstream, occurred under seemingly normal flow conditions between 1267 and 2359 cfs. The two passages between the Dresden Island and Marseilles pools occurred by a single Bighead Carp. This is the first inter-pool movement recorded for any Asian carp species within this telemetry program since its commencement in 2010. The Bighead Carp moved downstream, into the Marseilles pool on 17 September and back upstream into the Dresden Island pool on 22 September. Our preliminary conclusion is that Asian carp and Common Carp may utilize locks within the Upper Illinois River for inter-pool movement.

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

In 2010, 17 Bighead Carp were tagged and released into the Dresden Island Pool, near Moose Island at RM 276.0. Movements of these fish were recorded mainly through the use of mobile tracking and supplemented by two VR2W receivers at either end of the pool in 2011 and an additional receiver positioned into the Kankakee River in the spring of 2012. There has been a 52.9% (9/17) detection rate on these fish since their release date and lost tags may be explained

by commercial harvest efforts or emigration from the study area (Figure 3). Through 2012, all but two of these fish have remained active near the mouth of the Kankakee River, staying within a 2 mile radius of the confluence, utilizing habitat in both the Illinois and Kankakee Rivers. One Bighead Carp was observed to travel 12.5 miles upstream and was detected by a stationary receiver at the Brandon Road Lock on 19 June 2012 and was then detected returning to the Kankakee River by another receiver on 9 July 2012. The second Bighead Carp to move away from the area was recorded downstream of the Dresden Island Lock and continued approximately 11 miles to the backwater Hanson Material Service Slips within the Marseilles pool on 17 September 2012. The Bighead Carp was then recorded leaving the backwater habitat on 23 September and returned to the Dresden Island Pool on the same day. Based on the tagged fish data from this pool, our preliminary conclusion is that the leading edge of adult Asian carp prefers the habitat surrounding the mouth of the Kankakee River and has not continued to spread upstream in substantial numbers.

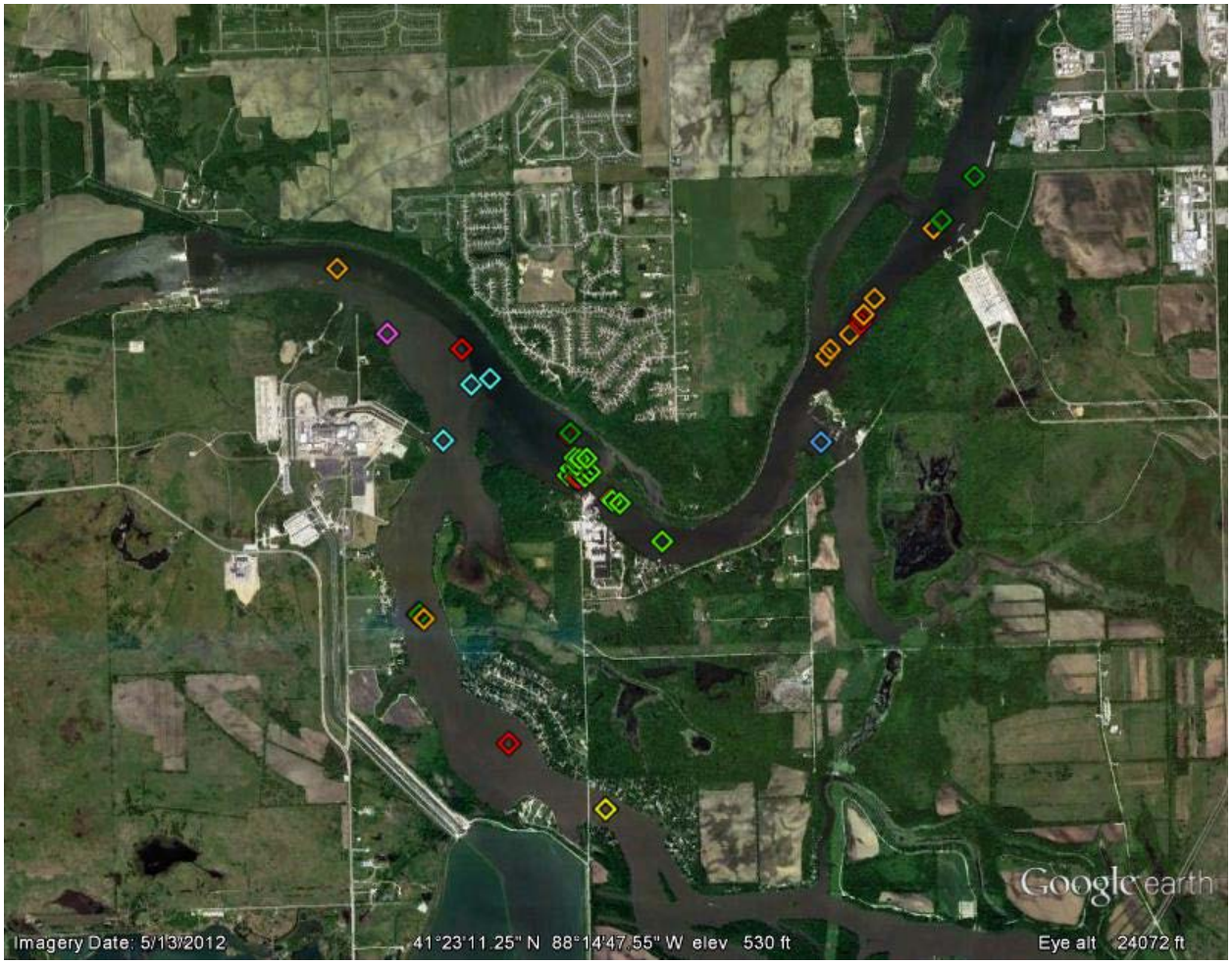


Figure 3: Individual fish, color-coded detection locations within the Dresden Island Pool of the Illinois River from April 2011 through November 2012. (Image provided by Google Earth)

In October of 2012, an additional 15 Silver Carp and 16 Bighead Carp were tagged and released within the Marseilles pool at the Hanson Material Service slips (RM 262.0) and the Stratton Park Boat Launch (RM 263.5) respectively. After one mobile tracking event in early November,

70.9% of the fish were detected utilizing habitat in backwater areas and side channels behind islands (Figure 4). Silver Carp traveled a mean distance of 2.44 miles (SD±1.89) from their release point while Bighead Carp traveled an average of 3.42 miles (SD±3.9). All fish had been captured via commercial netting in the Hanson Material Service slips. A two sample t-test assuming unequal variance showed no significant difference ($t=0.84$, $df=19$, $P=0.41$) between the distance traveled for the two species. None of these fish have been detected on stationary receivers positioned at the Marseilles and Dresden Island Locks.

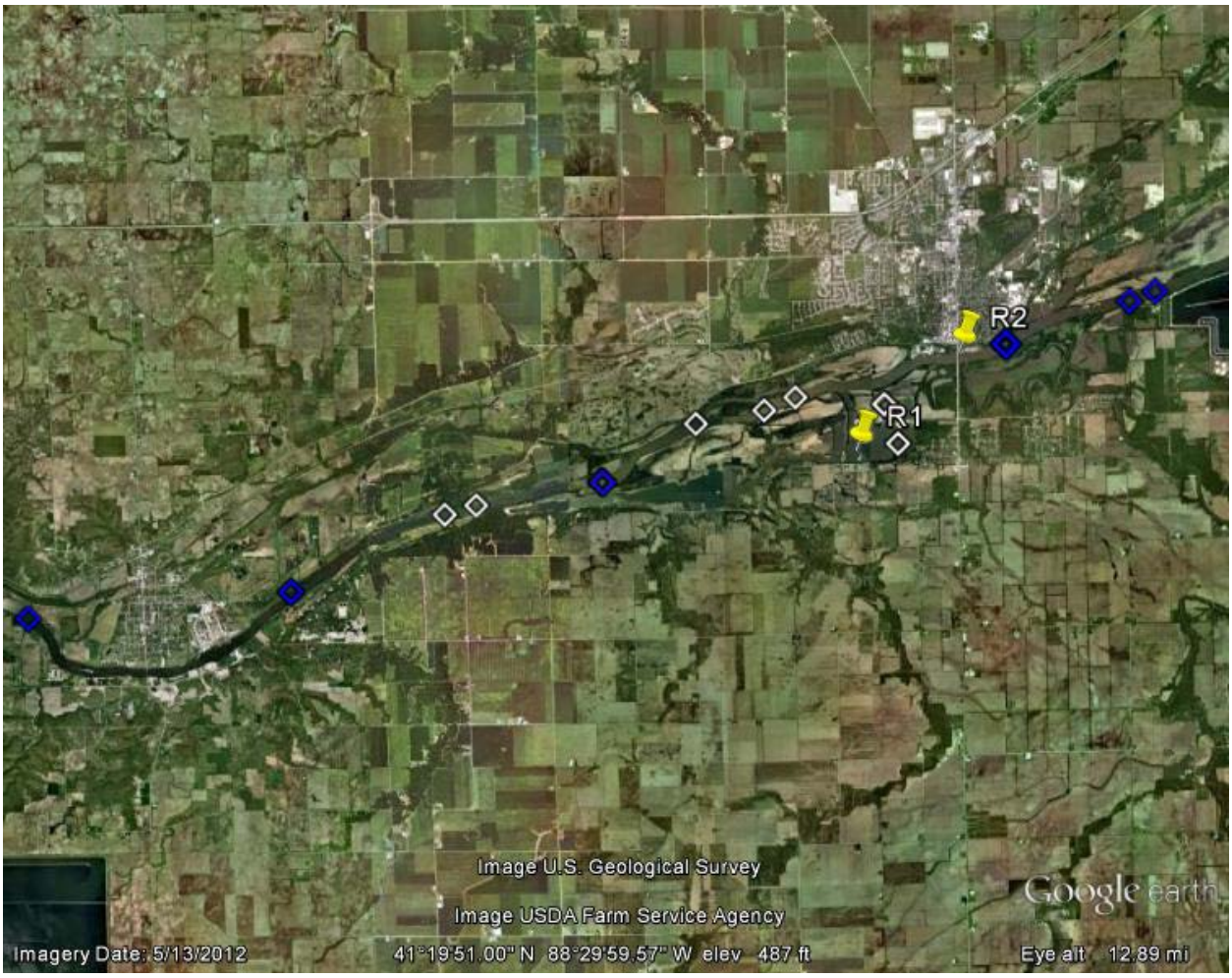


Figure 4: Map depicting mobile tracking detections of Bighead (Blue) and Silver (White) Carp three weeks after release within the Marseilles Pool. All Silver Carp were released from pin R1 while Bighead Carp were released from pin R2. (Image provided by Google Earth)

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. The small fish study should also be completed at the electric barrier system with an additional 15 fish to be tagged in the spring of 2013 with their movements and behavior to the electric field recorded and analyzed. Further investigation into the lock passage mechanics for fish passage at the Lockport Lock is also warranted. Past years data may indicate that fish are able to be flushed through the system during high flow events at this lock and dam.

Project Highlights:

- To date, 5.5 million detections have been acquired from 238 tagged fish
- Our preliminary conclusion from the small fish and adult fish telemetry studies is that the electric barrier system is effectively preventing all upstream passage of tagged fish.
- We have observed inter-pool movement of tagged Common Carp at all locks within the study area and one Bighead Carp at the Dresden Island Lock.
- Based on the few Asian carp tagged in Dresden Island pool, our preliminary conclusion is that the leading edge of adult Asian carp in Dresden Island pool has not changed but individual fish do scout ahead of the main front as far north as the Brandon Road Lock and Dam.
- Recommend 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.

Evaluation of Fish Behavior at the Dispersal Barrier

Aaron Parker; U.S. Fish and Wildlife Service - Carterville Fish and Wildlife Conservation Office.

Participating Agencies: U.S. Fish and Wildlife Service, Carterville Fish and Wildlife Conservation Office (lead).

Introduction: In order to prevent the upstream dispersal of fish, particularly invasive Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*H. nobilis*), from the Mississippi River Basin to Lake Michigan, a series of electrical barriers are operated by the U.S. Army Corps of Engineers (USACE) – Chicago District. The electric barrier system is located within a 2,100 ft length of the Chicago Sanitary and Ship Canal (CSSC), near Romeoville, IL, about 37 miles downstream of Lake Michigan.

Sparks et al. (2010) and Dettmers et al. (2005) were the first to directly test the effectiveness of the Demonstration Barrier, which was the first barrier installed in 2002. Sparks et al. (2010) recorded a radio-tagged Common Carp (*Cyprinus carpio*) breaching the Demonstration Barrier in April 2003. This breach was later determined to have coincided with the passage of a barge. During November 2003, Dettmers et al. (2005) passed encaged fish alongside a barge through the Demonstration Barrier and found that the effects of the electrical field were delayed when fish swam alongside the conductive (steel) barge hulls and some fish were never incapacitated as they swam through the barrier. Dettmers et al. (2005) attributed the delayed and non-incapacitations to a distortion of the electrical field by the barges.

Following the Dettmers et al. (2005) study, design modifications were made to two additional electrical barriers (Barriers IIA and IIB) to account for the barge-induced electrical warping. Barriers IIA and IIB were implemented in 2009 and 2011, respectively. The newer barriers cover a much larger area than the Demonstration Barrier and are capable of generating electrical fields of much higher intensity. The operating parameters of Barrier IIA were increased to 6.5 ms, 15 Hz, 2.0 V/in (hereafter summarized as 2.0 V/in) in August 2009 as a result of a pilot laboratory study performed by Holliman (2011) on Silver Carp ranging in size from 5.4 - 11 in TL. Barrier IIB operated at 2.0 V/in until 11/29/2011, when parameters were increased to 2.5 ms, 30 Hz, 2.3 V/in (hereafter summarized as 2.3 V/in) in response to intensive laboratory work done by Holliman (2011) on bighead carp that were 1.8 - 2.8 in TL. These are the current operating parameters as of this time for both Barriers IIA and IIB.

Objectives: We began performing field work within the barrier system in June 2011 when operating parameters were at 2.0 V/in and continued to work there following the change in operating parameters in November 2011 to 2.3 V/in. Our specific objectives were to 1) describe the behavior of fish within various parts of the barrier system, 2) determine the abundances of fish within various parts of the barrier system, and 3) describe the behavior of encaged fish that are pulled through one of the larger, high-intensity, barriers (Barrier IIA or IIB) using metal and fiberglass-hull boats and along various parts of a metal-hull barge.

Methods: Abundances and behaviors of feral fish within and near the electric barrier system were recorded using a dual-frequency identification sonar (DIDSON). The use of DIDSON by fishery scientists to obtain size, behavior, and abundance data is becoming increasingly common (e.g. Becker et al. 2011). A DIDSON device is capable of capturing consistent images regardless of turbidity and light level, however, DIDSON images are not sufficiently detailed to allow for species identifications (e.g. Moursund et al. 2003). We recorded DIDSON footage for seven weeks in 2012 at eight separate sites and ten sub-sites within each site for a total of 80 unique site recordings (See Figures 1 &2 and Table 1 for a full description of the sites). We recorded 800 minutes of DIDSON footage for six weeks focusing on the western canal wall directly over the high-voltage barrier arrays. Fish were measured with the DIDSON software measurement tool and the following behaviors were recorded: "swimming," "flight," "hovering," and "probing."

Gizzard Shad (*Dorosoma cepedianum*) collected from the CSSC were used in caged-fish trials. Asian carp were not used in the caged-fish trials for obvious escapement concerns. The cage used in the trials had a non-conductive PVC frame (63 in L x 23 in W x 35 in D) with 0.37 in bar monofilament mesh. The cage was mounted alongside the boat using custom-made mounts. A camcorder was mounted above the cage to record fish behavior. Five Gizzard Shad were placed in the cage and moved through one of three 377 ft sections of the CSSC moving from south to north (upstream). The sites that the caged fish were moved through were mid-channel and near the west wall of the CSSC over the entire array of electrical barrier structures, or a control area through the mid-channel of the CSSC away from any electrified water. Ten trial runs were performed at each of these sites in the canal. In addition to our regular caged-fish work at Barriers IIA or IIB, one day was spent moving 11 Common Carp and two Freshwater Drum (*Aplodinotus grunniens*) through the Demonstration Barrier using a fiberglass-hull boat. Recordings of caged fish were reviewed, separately, by two different observers. At each observation point, one of four different behaviors was recorded for each fish: "swimming," "flight," "floundering," or "incapacitation."

In addition to our scheduled caged-fish work, we also accompanied researchers from the USACE – Chicago District and USACE Construction Engineering Research Laboratory (CERL) – Champaign during a barrier voltage and field-mapping project involving metal-hull barges. During July, 2012, we were able to perform caged-fish runs with a PVC-frame cage (described above) mounted at the following four locations: 1) the side of a barge (four runs), 2) the stern of one barge in the corner or pocket of water that is adjacent to the tug vessel in a two-wide barge configuration (three runs), 3) in the exposed rake (sloped portion) at the front of a barge (two runs), and 4) with the cage mounted inside a pocket of water between a barge junction where the raked end of one barge was lashed to the square end of another barge (five runs).

In October, 2012, we performed additional caged-fish work with barges. Barge work in October focused on fish within the pockets of water between various barge junction configurations. Different barge configurations using caged fish were: raked end of the barge lashed to the bow of the tow vessel (four runs), two-barges, rake-to-rake lashed together (nine runs), and rake-to-square end configuration (five runs). We also repeated the rake-to-square end configuration using loose fish with brightly-colored floats tethered to them that were dropped into the pocket of water between the barge junction before the barge reached the barriers (15 runs).

Results and Discussion: A full analysis of data collected during 2012, with the current operating parameters of 2.3 V/in is ongoing. During the fall of 2011, when operating parameters were at 2.0 V/in, DIDSON recordings revealed that feral fish appeared to accumulate in large numbers below the highest-voltage area of the electric barrier system. We also observed the highest amounts of both hovering and probing behavior both below the barrier arrays and within the barrier arrays where the in-water voltage was highest. We also found that the larger fish accumulated further downstream from the highest concentration of electricity, whereas smaller fish (2.1 – 13.3 in TL) were able to penetrate further into the electric barrier system, including just below the highest electrical field between the narrow arrays, an area about two meters wide.

During 2012, when operating parameters were at 2.3 V/in, we found very few fish near the electric barrier system in the winter and spring and the fish recorded were generally further from the electric arrays than in the fall of 2011 when operating parameters were at 2.0 V/in. In the summer months, more fish appeared and accumulated below the electric barrier system, and fish began to penetrate further upstream into the electric barrier system than in the winter and spring. During the fall of 2012, we observed the greatest number of fish in and around the electric barrier system. Similar to fall of 2011, at 2.0 V/in, fish accumulated below the electric barrier system and were able to penetrate the furthest upstream into the electric barrier system, including immediately below the highest electrical field between the narrow arrays.

Velocity, conductivity, temperature, and dissolved oxygen showed no meaningful relationships to the numbers of fish that we saw throughout the year. However, a significant inverse relationship between average fish sizes and numbers of fish observed was detected, indicating that smaller fish were less repelled and could penetrate further into the electrical field. The phenomenon of electricity in water having a greater effect on larger fish is well known based on numerous electrofishing studies. The fish we observed immediately below the highest electrical field during the fall of 2012 were 3.6 – 4.9 in TL and were most likely Gizzard Shad based on visual identifications by field personnel of fish at the water surface. The fall is when YOY fish are likely at the ideal size to have enough strength to swim in the main channel of the CSSC and only be affected by the strongest electrical field. The fish that we observed immediately below the highest electrical field exhibited behavior indicative of an awareness of the field and no fish were directly observed breaching the electric barrier system.

Reverse flows (Provisional data-USGS CSSC Lemont Gauge), that occur in the CSSC as a result of lock and flood control operations, could potentially carry stunned fish through the electric barrier system and raise concerns about fish accumulating immediately below the electric barrier system. Also of potential concern is the barge traffic moving downstream causing water immediately adjacent to the barge to move in the opposite direction of the barge (return flow), which may temporarily reverse flows in the entire canal. There is continual concern that barges moving in any direction through the electric barrier system may warp the electric field. We are currently analyzing our data from our barge studies to further examine this potential problem.

Laboratory work addressing the risk of barge displacement of fish through the electric barrier system in the CSSC is currently underway at the USACE-CERL facility in Vicksburg, MS. We plan to further test the potential for barges to warp the electric field and facilitate upstream passage of fish by creating reverse flows next spring. We will place tagged Gizzard Shad

immediately below the high-field array where we have observed feral fish and track their movements following planned downstream barge movements. Results of these studies may have further implications on how barges navigate the electric barrier system.

During the fall of 2011, at the previous barrier operating parameters of 2.0 V/in, 270 Gizzard Shad were moved through the electric barrier system in cages. Eight of those fish did not become incapacitated (size range 3.3 – 3.8 in TL) when moved upstream next to an aluminum-hull boat. However, since the barrier operating parameters have increased to 2.3 V/in, all of the fish that we moved through Barriers IIA or IIB, along aluminum and fiberglass-hull boats, were incapacitated. Six out of 11 Common Carp that were moved through the Demonstration Barrier were not incapacitated; however, they did exhibit avoidance behavior while moving through the electric barrier system (e.g. rapid circling movements and attempts to swim downstream). The sizes of the non-incapacitated Common Carp were 15.6 – 25.7 in TL. The two Freshwater Drum (14.6 and 15.1 in TL) that were moved through the Demonstration Barrier were not incapacitated and did not exhibit any readily discernible avoidance behavior comparable to the Common Carp. A full analysis of the barge-fish behavioral data is not available at this time.

Recommendations: Based on our recent caged-fish results at Barriers IIA and IIB, we recommend that barrier operating parameters remain at no less than the current 2.3 V/in parameters. The results of our caged-fish work at the Demonstration Barrier lead us to recommend that scheduled and unscheduled outages be minimized to the greatest extent possible and response clearing events between the operating barrier and the Demonstration Barrier should take place as soon as possible. We found that fish abundances within and around the electric barrier system are not consistent throughout the year. Therefore, data from our studies and future studies should be used to determine when the best times to perform scheduled maintenance are in an effort to minimize any risk of fish passage. Further study and analysis of the effects that barges may have on the hydrology and electrical field in the electric barrier system area and how this may affect fish behavior should occur.

Project Highlights:

- Fish accumulate below the barrier arrays in higher numbers in the summer and fall, small fish were recorded immediately below the highest electrical field.
- All caged fish that were moved through Barrier IIA or IIB after operating parameters were increased to 2.3 V/in were incapacitated; however, two Freshwater Drum that were moved through the Demonstration Barrier were not and did not show avoidance behavior.
- Two weeks of intensive caged-fish work involving barges were performed and plans for future evaluations of barge-fish interactions are underway.

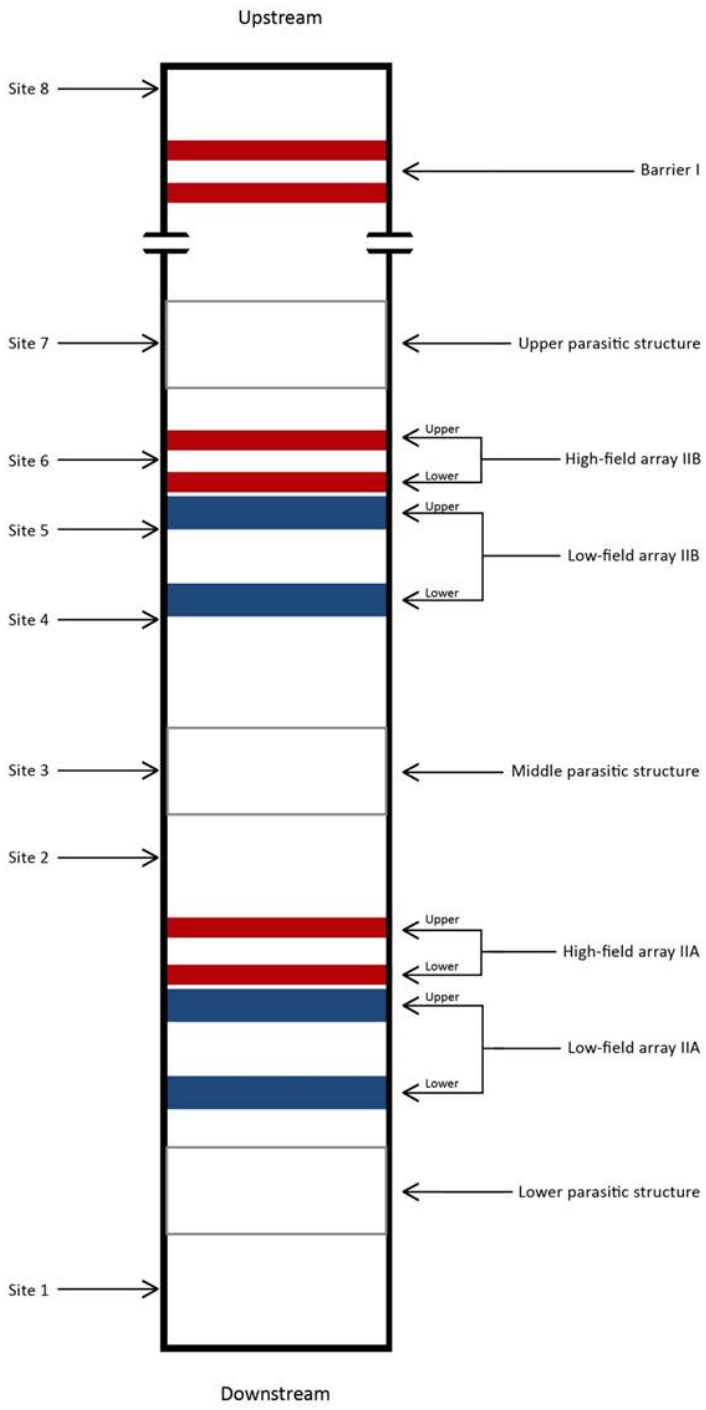


Figure 1. Schematic of the electric barrier system within the CSSC where DIDSON images are recorded. Note: drawing is not to scale and represents DIDSON recordings taken if Barrier IIB was operating.

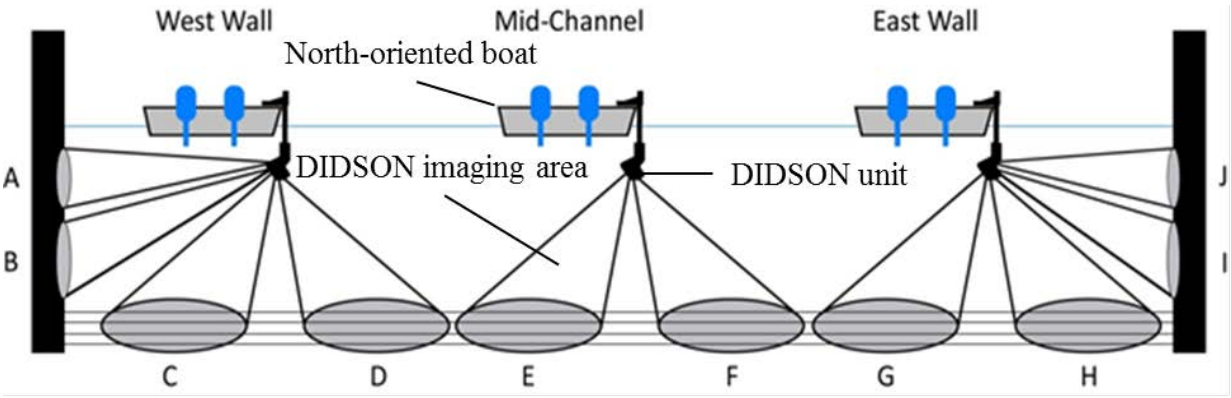


Figure 2. Cross-sectional illustration of the CSSC displaying ten sub-sites (A-J) across the canal where DIDSON footage was recorded within sites 1-8 from a north-oriented boat. Note: only one boat was used at a time to record one sub-site.

Table 1. Description of DIDSON recording sites.

Site Number	Description
Site 1	Area downstream of all electrical structures where water-borne electricity is typically minimal.
Site 2	Area immediately downstream of the first operating parasitic structure where water-borne electricity is typically minimal
Site 3	Middle of first operating, downstream parasitic structure
Site 4	Area immediately downstream of the first operating wide-array, low-field structure
Site 5	Area immediately downstream of the second electrode bank of the wide-array structure
Site 6	Area between the two narrow, high-field arrays where voltage is typically highest
Site 7	Middle of first operating, upstream parasitic structure
Site 8	Area upstream of all barrier structures where voltage is typically minimal

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); Illinois Department of Natural Resources and Metropolitan Water Reclamation District of Greater Chicago (field support)

Introduction: The upper Des Plaines River 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). It is possible that Asian carp could gain access to the CSSC upstream of the electric barrier system 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 and consists of concrete barriers and 0.25 in mesh fencing built along 13.5 mi 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. It is critical to understand the Asian carp population status, monitor for any potential spawning events, and determine the effectiveness of the physical barrier to help inform management decisions and direct removal actions.

Objectives: There are two major objectives for this study:

1) Monitor Bighead and Silver Carp and their spawning activities in the Des Plaines River above the confluence with the CSSC; and
2) Monitor for Bighead 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: Three sites were chosen to monitor for Asian carp using electrofishing and short term sets of gill and trammel nets: downstream from the Hofmann Dam in Riverside, the Columbia Woods area near Willow Springs, and upstream from the Lemont railroad bridge near Lemont (Figure 1). Lemont Railroad Bridge was sampled on 05/01/12, 06/19/12, and 10/24/12; Columbia Woods on 05/02/12, 06/20/12, and 10/25/12; Hofmann Dam on 05/03/12 and 6/20/12. Sampling at Hofmann Dam was limited due to access issues during low water and dam removal operations. Columbia Woods and Lemont Railroad Bridge were sampled using pulsed-DC electrofishing. Hofmann Dam was sampled using 3-phase AC electrofishing and pulsed-DC electrofishing. Nets used included 0.75-2.0 inch experimental gill nets, 3.5 inch trammel nets, 2.0 inch gill nets, 3.0 inch gill nets, and 4.0 inch gill nets. Nets were set short term and fish were driven towards the nets.

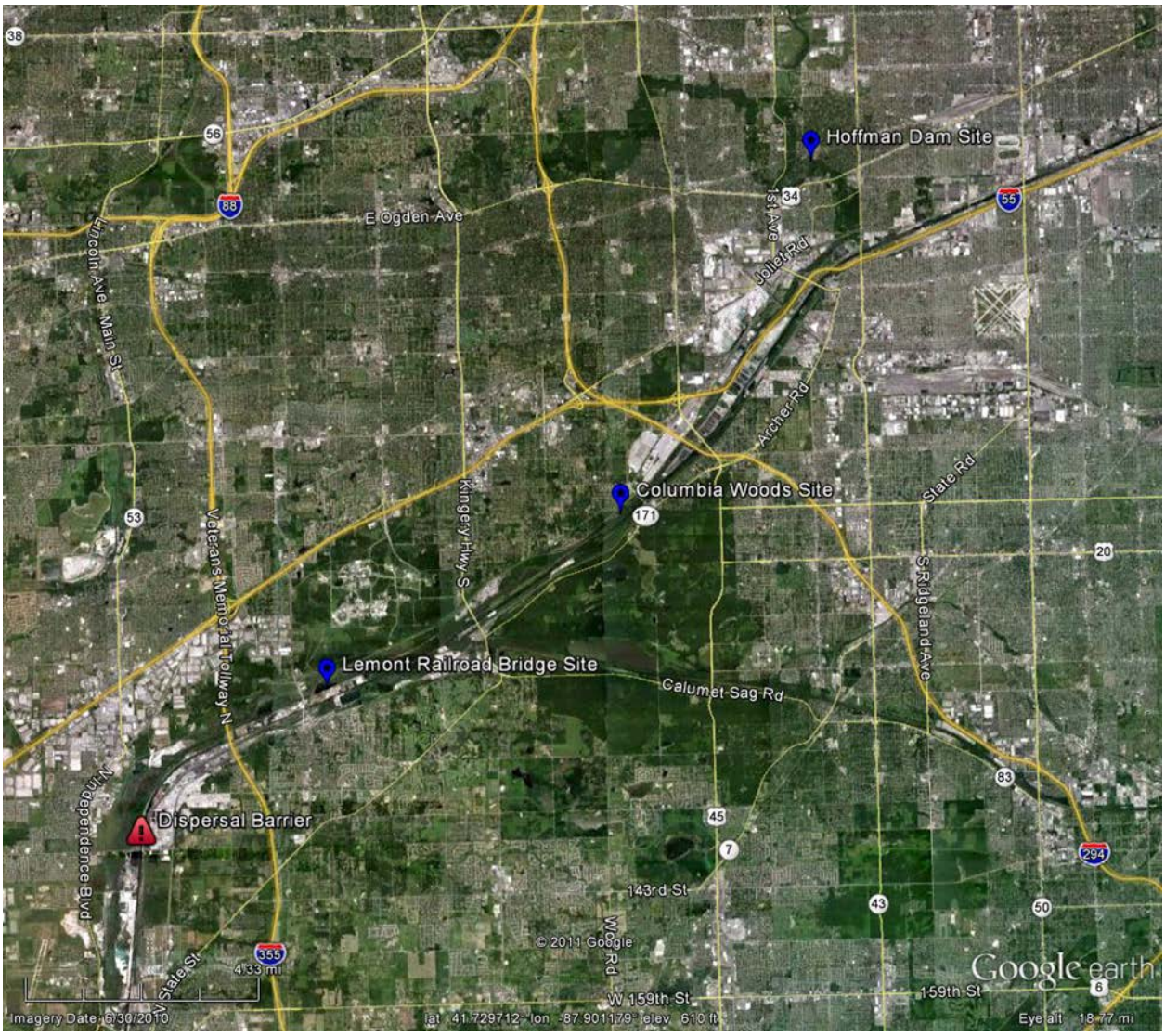


Figure 1. Asian carp sample sites on the upper Des Plaines River (map created with Google Earth).

Results and Discussion: Electrofishing at the three sites resulted in the capture of 3,112 fish representing 41 species from 11 families and one hybrid group (Table 1). A total of 12.6 hours were spent electrofishing: 5.6 hours at Lemont, 5.0 hours at Columbia Woods, and 2.0 hours at Hofmann Dam. We collected 63 fish representing 15 species from seven families in gill and trammel nets (Table 1). A total of 21 sets covering 2,066 yards were fished for a combined total of 24.2 hours. No Asian carp were captured or observed.

Hofmann Dam previously provided what was likely an impassable barrier (Pescitelli and Rung 2010). The dam's removal was initiated in June 2012 and has eliminated a barrier to upstream migration by Asian carp. It should also be noted that removal of the dam may have made the upper Des Plaines River more suitable for a spawning event by Asian carp. Sampling may be expanded in the future to include any areas upstream that may provide favorable habitat. The Lemont and Columbia Woods sites will continue to be monitored in 2013, and sampling may

Table 1. Total number of fish captured by electrofishing and netting on the upper Des Plaines River in 2012.

	Electrofishing		Netting	
Species	**Total Catch**	**% of catch**	**Total Catch**	**% of catch**
Gizzard Shad >6"	113	3.63%	2	3.17%
Gizzard Shad <6"	8	0.26%		
Common Carp	567	18.22%	29	46.03%
Goldfish			1	1.59%
GoldfishXCarp Hybrid			1	1.59%
River Carpsucker	2	0.06%		
Quillback	5	0.16%		
Bigmouth Buffalo			1	1.59%
Smallmouth Buffalo			1	1.59%
White Sucker	61	1.96%	1	1.59%
Spotted Sucker	8	0.26%	2	3.17%
Channel Catfish	184	5.91%	4	6.35%
Yellow Bullhead	16	0.51%		
Largemouth Bass	270	8.68%	2	3.17%
Smallmouth Bass	7	0.22%	1	1.59%
Bluegill	490	15.75%		
Green Sunfish	112	3.60%		
Pumpkinseed	9	0.29%		
Orangespotted Sunfish	56	1.80%		
Warmouth	4	0.13%		
Longear Sunfish	1	0.03%		
Hybrid Sunfish	1	0.03%		
Rock Bass	12	0.39%		
White Crappie	1	0.03%		
Black Crappie	105	3.37%	2	3.17%
Golden Shiner	40	1.29%		
Bluntnose Minnow	370	11.89%		
Fathead Minnow	31	1.00%		
Spotfin Shiner	316	10.15%		
Emerald Shiner	4	0.13%		
Spottail Shiner	76	2.44%		
Sand Shiner	92	2.96%		
Hornyhead Chub	4	0.13%		
Creek Chub	5	0.16%		
Blackstripe Topminnow	17	0.55%		
Western Mosquitofish	2	0.06%		
Northern Pike	34	1.09%	11	17.46%
Walleye	1	0.03%		
Sauger	27	0.87%	1	1.59%
Yellow Perch	1	0.03%		
Blackside Darter	7	0.22%		
Johnny Darter	1	0.03%		
Logperch	1	0.03%		
White Perch	1	0.03%		
Bowfin	35	1.12%		
Longnose Gar	14	0.45%	4	6.35%
Oriental Weatherfish	1	0.03%		
Totals	3112		63	

be expanded into adjacent areas that also provide favorable habitat. No high water events occurred in 2012 to allow lateral water flow from the Des Plaines River into the CSSC.

Recommendations: It is recommended that monitoring for the presence of Asian carp juveniles and adults in the upper Des Plaines River continues in 2013. Additional areas with accessibility and favorable habitat throughout the reach will be considered for sampling, especially in areas upstream of the former Hofmann Dam. 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.

Project Highlights:

- Captured 3,175 fish representing 44 species from 13 families and two hybrid groups during 12.6 hours of electrofishing and 21 net sets on the upper Des Plaines River.
- No Asian carp were captured or observed.
- Recommend continued monitoring for the presence of Asian carp adults and/or juveniles at the three sites in the upper Des Plaines River and continued investigations in the area of overtopping events.

Asian Carp Gear Efficiency and Detection Probability Study

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Jonathan A. Freedman, Steven E. Butler, Matthew J. Diana, David H. Wahl**;** Illinois Natural History Survey

Participating Agencies: Illinois Natural History Survey (lead), Eastern Illinois University (support), Western Illinois University (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 been evaluated. Understanding 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 abundances of Asian carp. Data gathered from gear evaluations can also be used to model detection probabilities and occupancy rates for Asian carp. Determining the probability of detecting Asian carp with each sampling gear in different areas of the Illinois Waterway would allow for establishment 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

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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 will likely 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. 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.

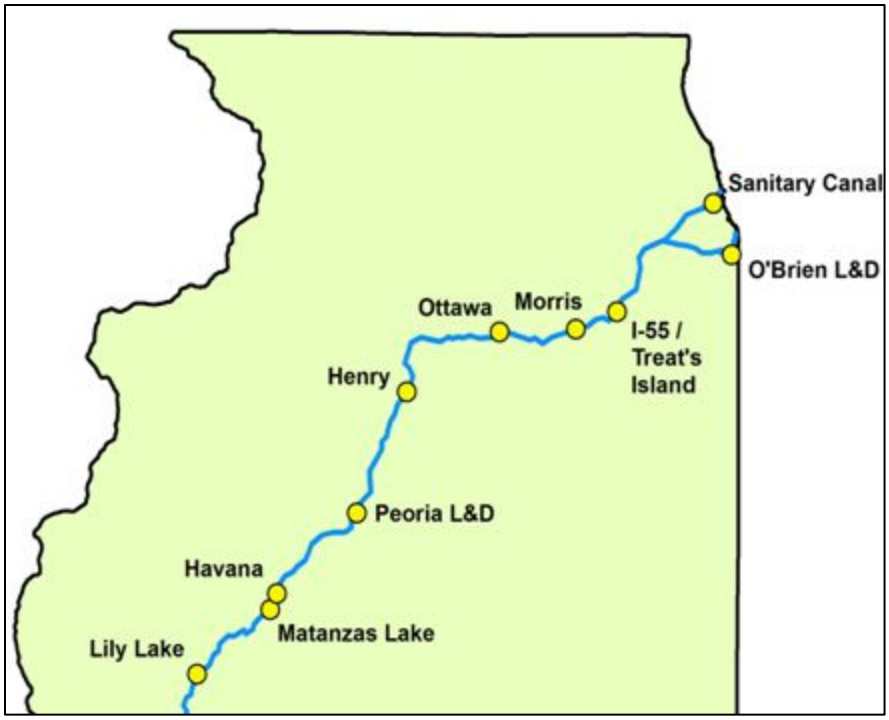

Figure 1. Map of gear evaluation sites in the Illinois Waterway.

Gear / Method	Target	Effort per site-visit
Hoop net	Adults	12 net-nights
Trap net	Adults	8 net-nights
Trammel net w/ pounding	Adults	4 sets
Large mesh purse seine	Adults	4 hauls
Large mesh gill net – sinking	Adults	4 x 4 hour sets
Small mesh gill net – sinking	Juveniles	4 x 4 hour sets
Small mesh gill net – floating	Juveniles	4 x 4 hour sets
Mini-fyke net	Juveniles	8 net-nights
Small mesh purse seine	Juveniles	4 hauls
Midwater trawl	Juveniles	4 x 5 minute tows
Cast net	Juveniles	3-4 hauls
Beach seine	Juveniles	3-4 hauls
DC electrofishing	Both	6 x 15 minute transects
Hydroacoustics	Both	2 x 15 minute transects

Results: Each site was sampled three times from April 23 to October 5, 2012. Using all gears, we captured a total of 2,042 Asian carp, comprising 1,712 Silver Carp, 142 Bighead Carp, and 185 hybrid Asian carp. Electrofishing was the most effective gear for sampling Silver Carp (77% of Silver Carp), followed by hoop nets (7%) and large mesh purse seines (6%). Hybrids were also most effectively captured by electrofishing (66%), followed by hoop nets (15%), fyke

nets (8%), and trammel nets (6%). Bighead Carp were most effectively captured using hoop nets (57%), trammel nets (21%), and fyke nets (9%).

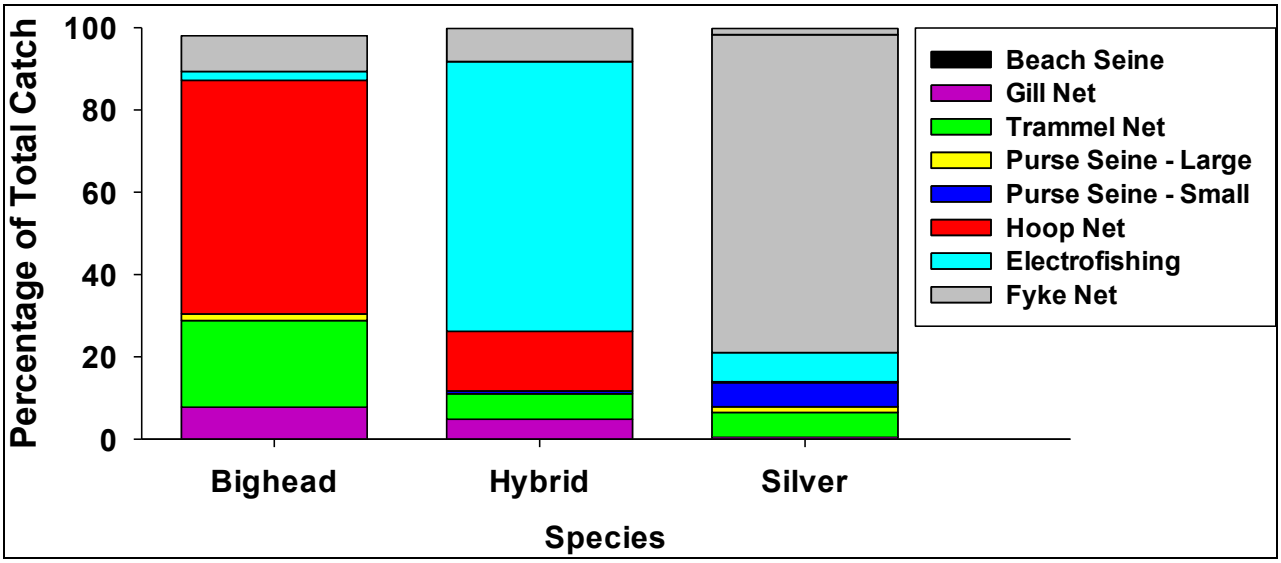

Figure 2. Percentage of total catch caught by each gear of Silver, Bighead, and hybrid Asian carp in the Illinois River in 2012.

No Asian carp were captured above the electric barrier system in the CAWS or at the I-55/Treat's Island site in the Dresden Island Pool. The furthest upstream we captured Asian carp was at Morris in the Marseilles Pool. The highest abundance of Silver Carp was at Henry (Peoria Pool), whereas the highest abundance of Bighead Carp was at Havana and hybrid Asian carp was at Matanzas Lake, both in the LaGrange Pool.

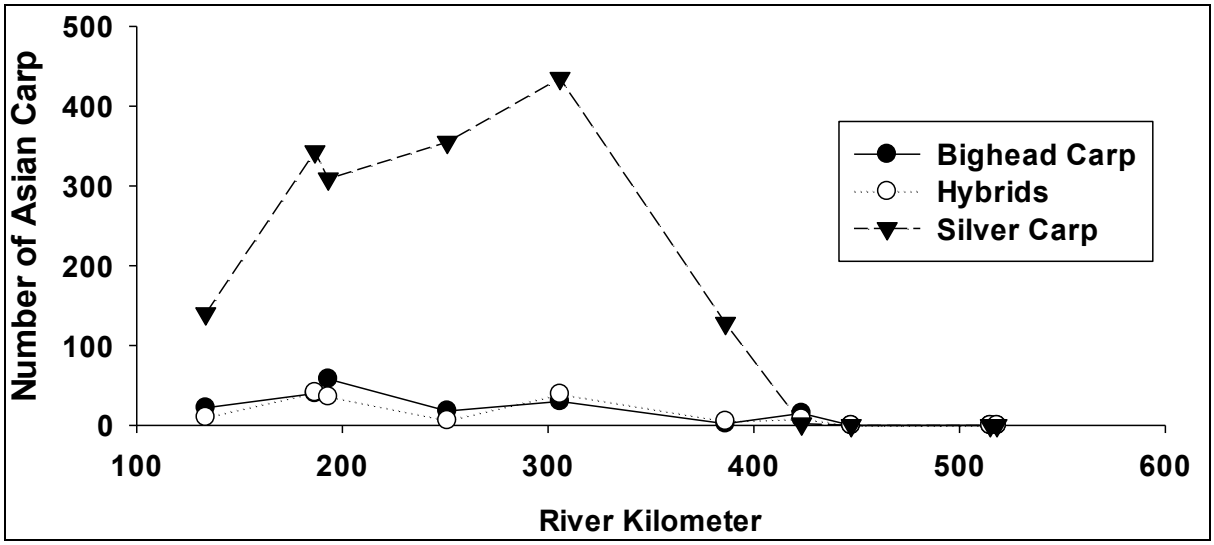

Figure 3. Total number of Asian carp caught at each sampling site in the Illinois River in 2012. River kilometer is measured as distance upstream from the Mississippi River.

One age-0 (140 mm) Silver Carp was captured at Peoria Lock & Dam (river kilometer 251) during fall sampling. We caught no age-0 Bighead or hybrid Asian carp. We caught 895 Asian carp <500 mm in length, mostly in the LaGrange and Peoria Pools with the highest abundance at Henry. One age-1 Asian carp was caught at Ottawa in the Starved Rock Pool.

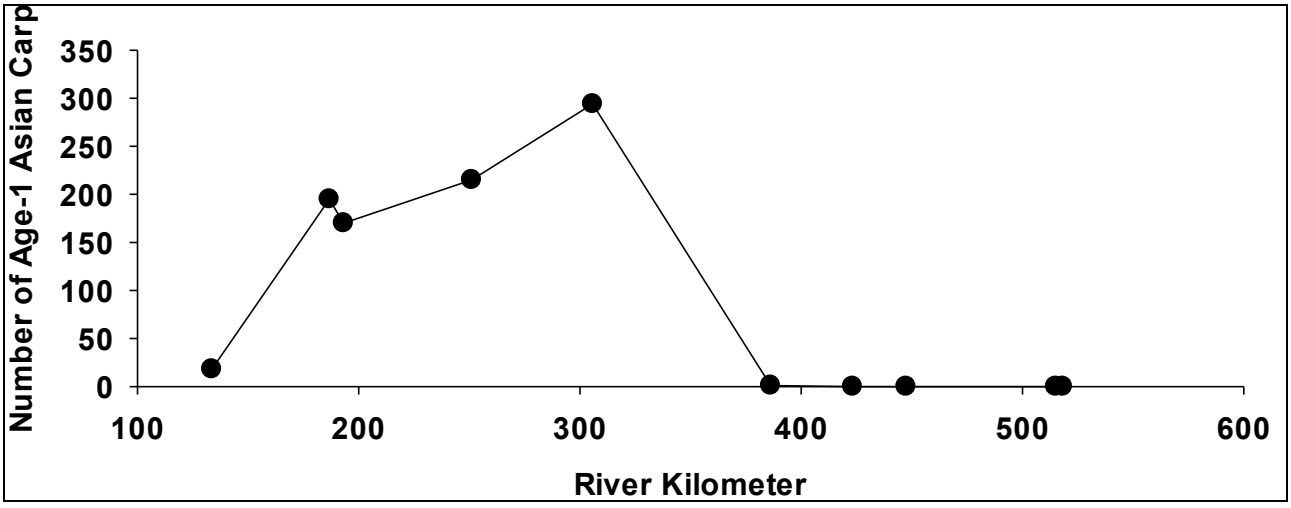

Figure 4. Number of possible age-1 (<500 mm) Asian carp caught at each sampling site in the Illinois River in 2012. River kilometer is measured as distance upstream from the Mississippi River.

Discussion: All taxa of Asian carp were most abundant in the LaGrange and Peoria pools; relative abundance decreased through the Starved Rock and Marseilles pools, and no Asian carp were captured or observed in the Dresden Island Pool or the CAWS. Gears targeting juvenile Asian carp (beach seines, small mesh purse seines, midwater trawls, cast nets, and mini fyke nets) were generally effective at capturing small fishes; however, few Asian carp were captured. Overall catch of age-0 fish was low in 2012, consistent with observed poor recruitment in the system since 2007. While Asian carp may reach 500 mm by age-2, using the 500 mm threshold to define age-1 Asian carp may overestimate the total number of age-1 fish. Further research is therefore needed to refine length-at-age estimates. However, the virtual absence of Asian carp less than 500 mm in the Starved Rock and Marseilles pools is notable, and supports other data suggesting that spawning may not occur in upper reaches of the Illinois River (see Larval Fish and Productivity Monitoring summary). Sampling gears varied in effectiveness, with Silver Carp being most effectively sampled using electrofishing, whereas Bighead Carp were most effectively sampled using passive overnight gears and trammel nets, and hybrid Asian carp were somewhat vulnerable to electrofishing and passive gears.

Recommendations: Further sampling will be required to refine optimal sampling protocols and determine annual trends in Asian carp abundance. Because 2012 represented another poor recruitment year for Asian carp, sampling during high recruitment years will be required to determine sampling efficacy for age-0 Asian carp across gears. Analysis of 2012 hydroacoustic data is underway. Video collected during electrofishing transects is being analyzed as a potential alternative metric for determining Silver Carp density. Data analysis will include relative gear efficiency, occupancy modeling, and detection probability modeling.

Project Highlights:

- Asian carp relative abundance was highest in the LaGrange and Peoria Pools; no Asian carp were caught upstream of Morris (Marseilles Pool), and none were caught in the CAWS.
- Possible age-1 Asian carp (<500 mm) were relatively abundant in the LaGrange and Peoria Pools, but only one was caught in the Starved Rock Pool, and none in the Marseilles Pool. Only one age-0 Asian carp (<300 mm) was captured (at Peoria Lock & Dam, LaGrange Pool).
- Electrofishing was the most effective gear for sampling Silver Carp and hybrid Asian carp, while hybrids were also captured in hoop nets. Hoop nets, trammel nets, and fyke nets were the most effective gears for capturing Bighead Carp.
- Recommend further sampling to refine optimal sampling protocols and determine annual trends in Asian carp abundance. Because 2012 represented another poor recruitment year for Asian carp, sampling during high recruitment years will be required to determine sampling efficacy for age-0 Asian carp across gears.

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 Asian carp
- keep costs within an affordable range for commercial fishermen
- be used in habitats specific to where large densities of Asian carp occur
- be used for mass density reductions
- use newer technologically advanced materials (high density polyethylene)
- reduce by-catch
- target all sizes of Asian carp

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: An oceanic purse seine was used to encircle and bottom purse around large schools of Asian carp. A floating 600 ft. long net X 12 ft. deep with #22 twine and 5.25 stretch nylon mesh was custom built for the trials. The net has 3 removable panels of 200 ft. each. Trials sites were performed at two locations. Trial one was conducted during May at a Missouri River scour that measured 34 ft. deep and the second trial was during June at an oxbow lake in Iowa that was 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 Asian 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 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 600 ft. 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 Silver Carp. It appears that Silver 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 the jumping ability of Silver Carp. There may still be opportunity to capture Bighead Carp, however observing large schools of fish to target will be a challenge, likely requiring some form of SONAR to locate. 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 Channel 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

Paupier (Butterfly Net)

Introduction: In the bays of Louisiana, paupier nets are used to capture small bait and commercial fishes as well as shrimp. We sought use of the same technique for Asian carp. The purpose of our trials was to test multiple prototype designs until one was valued as the final product. Therefore, data was more observational in terms of capture relative to observed abundance. Therefore, accounting of fish captured was not important so much as number of fish observed to escape. We did not value the gear unless it was a better tool in terms of efficiency and cost relative to a standard trammel or gill net deployment. As such, if we observed 100 fish escaping to ten fish captured and $20 spent in fuel the gear was deemed not effective and sent back to be modified. Results therefore reflect whether the gear worked or not and for what approximate fish size rather than CPUE. We worked with our net maker on a weekly basis shipping nets back and forth for modifications throughout the summer until we found a suitable design.

Methods: We deployed two rectangular custom trawl nets off each side of the boat. Each net fished from 0.75 meters above the surface of the water to 2 meters below the surface. The original trawl was 10 meters long with a single shell trawl and cod end, but the final version was 7 meters to avoid interference with the outboard motor. Several net materials were tried including nylon, polyethylene and HDPE (High Density Polyethylene). Mesh ranged from 5

inch stretch nylon, to 4 inch stretch HDPE. The original version of nylon resembled a standard trawl, but subsequent modifications included an inner fyke due to fish escapement. Eight net designs and sizes were used to develop one functioning net. Trials were performed in the Illinois River, Missouri River dike holes and Missouri River tributaries. Initial trials of the nylon and polyethylene were done in December and April and the improved HDPE versions were performed from July through September.

The net rigging consisted of an aluminum 2 meter high square mast frame installed inside the boat 3 meters from the bow. The frames that held the net were of two sizes and built of trussed aluminum. The first size was 2.7 meters long x 2 meters deep and the second was 4 meters long by 2 meters deep. The frames were lifted with electric winches installed on the top of the mast. The frames could be installed at different attachments along the mast allowing us to fish at varied depths above and below the water surface. We obtained boat speeds of 4.8 mph.

We used a separate boat with a DIDSON camera to observe fish interaction with the nets. This was done on two separate occasions with a different suite of prototypes.

Results and Discussion: Throughout the many renditions of net prototypes, we concluded that the speed of the boat was the key to capturing Asian carp (especially adults). In addition, the inside fyke was instrumental to retaining fish in the net. Adult Asian carp could easily be encircled through the front of the frame, but would either herd within the net or bump the net and swim back out. Many fish jumped into the net and were as likely to first swim towards the back of the net as swim out of it. This behavior suggested that the fyke could be used to hold the fish if they could be captured before being aware of the opening. This was verified through the use of a DIDSON camera. Internal fykes and mesh types and sizes were experimented with to find one design that best captured adult Asian carp. That design was made out of 4 inch stretch HDPE and included an internal fyke that quickly forced the fish to a 0.25 m funnel. Once the fish entered the inner funnel they could not escape. Six different funnel designs were tested in the process to find one that performed best. Despite the success of the funnel, we still conclude at this time that for adult fish, the net in the 4 m or 2.7 m version will not be as effective as other standard entanglement gears when used in the summer (we have not used the final version of the net in colder temperatures). However, fish in the age zero to age one range were easily captured and could not evade the net and were readily captured in the winter months of 2011 without the HDPE or inner fyke.

Our best success was observed in September 2012 using the final prototype version of the 2.7 m HDPE net. During those trials we did 5 minute trawls in clear water of a Missouri River tributary where we could observe fish movement down to 1 meter. We could assess visually whether fish were avoiding the net, swimming in and back out, or passing through the inner fyke. During these trawls dozens of juvenile fish were readily captured on each trawl and no escape was observed if the fish entered the net. Adult Asian carp still evaded the net. We suggest that the net itself is effective to entrain Asian carp, but the larger Asian carp have enough burst swimming speed to escape unless they happen to be disoriented and swim into the inner fyke. However, juveniles lack the burst speed needed to elude the inner fyke and are readily captured. The actual number of small sized fish was not determined since the cod bags were designed for adult fish.

On shallow banks of the Illinois River, we observed slightly better success with adult fish in water depths less than one meter. In these habitats, the fish would jump and enter the net disoriented allowing them to slip into the inner fyke without avoidance. We will capitalize on this behavior with an additional prototype net designed for jumping fish. We also have not sampled expansive shallow backwaters where high densities of these fish would be available. There is a danger in using this net in flowing water. Average summer flows of the Illinois River were not a hazard during our trials and moderate flows could be mitigated by going upstream.

Recommendations: Although we are still in the trial phase of testing, our results suggest that this gear could be used to harvest juvenile Asian carp where other traditional nets would not be effective due to by-catch. We also see a niche in removal of young Asian carp in nursery areas of very shallow oxbow lakes or cut-off backwaters to prevent the fish from recruiting back to the main river. This gear has not been tested in those areas. The cost to outfit a boat with rigging and a net will be about $3,500.

Project Highlights:

- The paupier captures juvenile Asian carp and could be used for this purpose
- Adult Asian carp were not readily captured and there may only be a specific temperature or habitat for which the gear is effective
- Appears to be a valuable tool for sampling juvenile Paddlefish

Unconventional Gear Development Project

ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Jonathan A. Freedman, Steven E. Butler, Matthew J. Diana, David H. Wahl; Illinois Natural History Survey

Participating Agencies: Illinois Natural History Survey (lead), Illinois Department of Natural Resources (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 in 2011 to discuss development of gears specifically targeting Asian carp in areas of low density and in the deep-draft channels of the CAWS. This committee decided to pursue purchase and 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. A pilot study was also recommended for assessing the effectiveness of corn or soybean meal/chaff as a surface attractant for Asian carp. 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 in the upper Illinois/Des Plaines River and the CAWS.

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 the effectiveness of gear and combination system prototypes in areas with low to moderate Asian carp population densities.

Methods: Unconventional gears were evaluated at multiple sites in order to evaluate their effectiveness across a range of Asian carp densities. Large hoop nets and surface-to-bottom gill nets were set at Havana (LaGrange Pool), Peoria Lock and Dam tailwaters (LaGrange Pool), Hanson Material Services (HMS)-East Pit (Marseilles Pool), and at Western Avenue (CAWS; Lockport Pool). Great Lakes trap (pound) nets were deployed at Lake Calumet (CAWS; O'Brien Pool), and at HMS-East Pit. All gears were evaluated for the numbers and sizes of Asian carp and other fishes they are 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 sinking gill nets (45.7 m long x 1.8 m depth; 1.9, 2.5, 3.2, 3.8, 5.1 cm mesh), 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).

- 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 (1-3 weeks) at each site during summer and fall. Pound nets were checked periodically (1-7 day intervals, based on catch rates) during each set, at which times all captured fish were removed from the pots for identification and measurement.
- The use of soybean meal as a surface attractant for Asian carp was evaluated at two sites (Lily Lake, Peoria Lock and Dam Tailwater) in the LaGrange Pool, with two test periods conducted at each site. During each test period, approximately 5.7 kg of soybean meal was spread across the water's surface and allowed to drift freely until dissipated (approximately 30 minutes). Field crews visually monitored the area being tested for any indication of Asian carp or other fish activity during these time periods.

Results: In 2012, two Great Lakes trap (pound) nets were set for 107 net-days at Lake Calumet, resulting in the capture of 1,051 fish (10 fish/net-day). No Asian carp were captured from Lake Calumet during these efforts. Two pound nets were set for 70 net-days at HMS-East Pit, capturing 4,341 fish (62 fish/net-day). During these efforts, 705 Asian carp (512 Bighead Carp, 85 Silver Carp, and 108 hybrids) were captured.

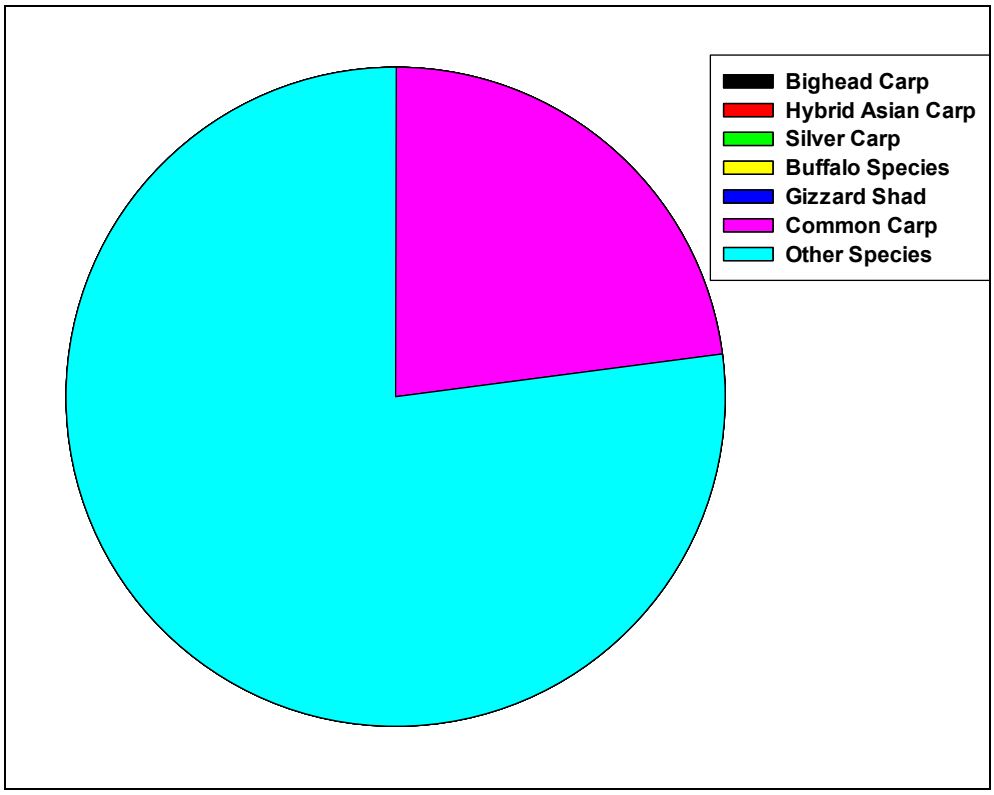

Figure 1. Relative catch of Asian carp and other common species in the Great Lakes trap nets at HMS-East Pit in 2012.

In 2012, surface-to-bottom gill nets were more effective at capturing Bighead, Silver, and hybrid carp (2.8 total Asian carp per 4-hour set) than large mesh sinking gill nets (0.45 per set), small mesh floating gill nets (0.3 per set), or small mesh sinking gill nets (0.05 per set). We found similar catch rates per unit area for surface-to-bottom (5.0 Asian carp per 1,000 m^2 of net) and large mesh sinking gill nets (5.5 per 1,000 m^2); small mesh floating gill nets (2.2 per 1,000 m^2) and small mesh sinking gill nets (0.6 per 1,000 m^2) had lower catch rates per unit area.

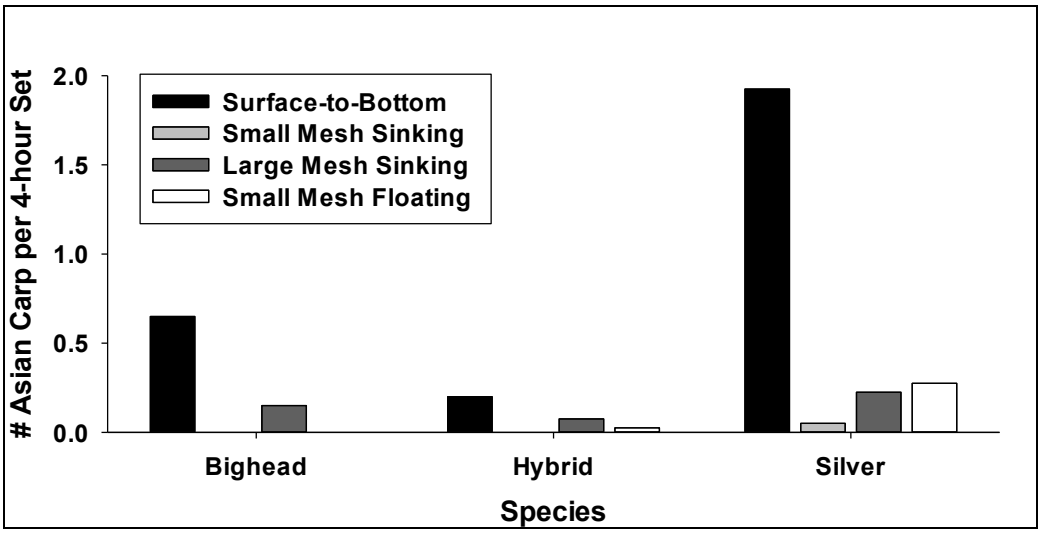

Figure 2. Number of Asian carp caught per 4-hour gill net set in the Illinois River in 2012.

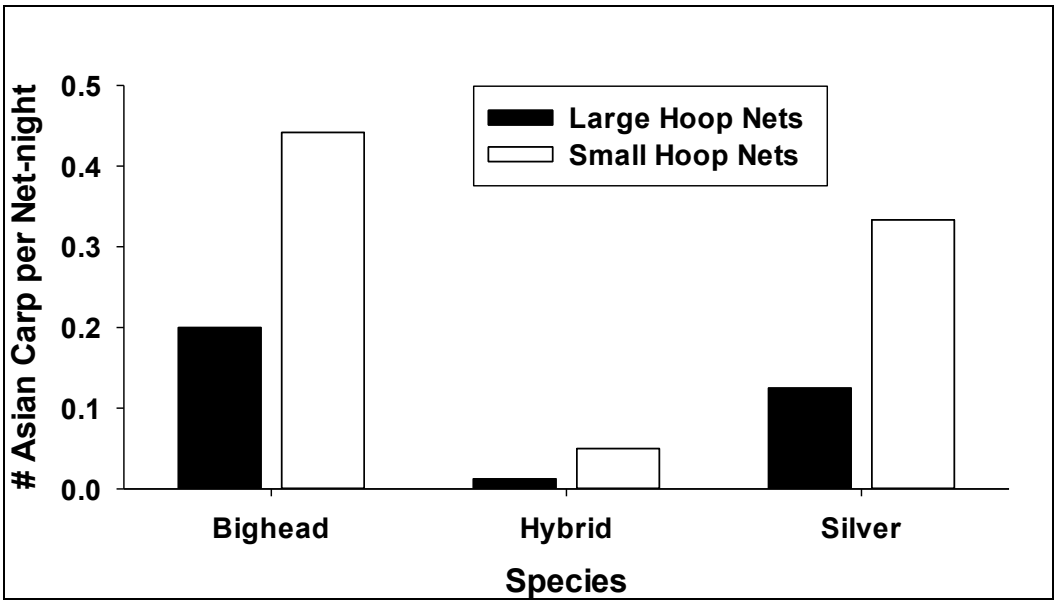

Figure 3. Number of Asian carp caught per hoop net net-night in the Illinois River in 2012.

Small (standard) hoop nets caught more Bighead, Silver, and hybrid carp (120 net-nights; 0.83 total Asian carp per net-night) than the large hoop nets (80 net-nights; 0.34 per net-night) in

2012.The use of soybean meal as a surface attractant was tested on four occasions. No Asian carp or other fish were observed feeding on soybean meal during any of these test periods.

Discussion: Great Lakes trap nets proved extremely effective at capturing fish at both Lake Calumet and HMS-East Pit. While no Asian carp were captured at Lake Calumet, the gear did prove extremely effective at capturing Asian carp at HMS-East Pit. One of the nets in Lake Calumet was vandalized on three separate occasions, demonstrating the need for greater education, public relations, and law enforcement.

The surface-to-bottom gill nets were tied down from 8.5 m to 6.1 m depth. Although they caught more fish than the traditional gill nets per 4-hour set, when calculated as catch per unit area the surface-to-bottom gill nets had slightly lower catch rates than the large mesh sinking gill nets. Both small mesh gill net types were less effective at capturing adult Asian carp in per unit area and per 4-hour set. However, 2012 was another poor recruitment year for Asian carp with very few age-0 fish caught (see Evaluation of Gear Efficiency and Asian Carp Detectability summary) and these smaller mesh sizes target smaller fish, thus further study will be required to test their efficacy.

Surprisingly, small hoop nets were more effective at capturing Asian carp than were the new large hoop nets. Further study is required to determine whether this is a factor of small sample size, patchy distribution of fish in the river, or whether the large hoop nets truly are less effective at capturing Asian carp.

Recommendations: Further sampling will be required to refine optimal sampling protocols and efficacies for these novel gears. The Great Lakes trap nets represent a possible tool for long-term monitoring in standing or low-flow areas, but may represent targets for vandalism and may not be appropriate for setting in flowing water. In 2013 we will identify locations in the LaGrange or Peoria Pools to further test this gear. The surface-to-bottom gill nets are effective at capturing Asian carp, and their efficiency should continue to be evaluated relative to other gears. Likewise, while large hoop nets appeared to be less effective than small hoop nets at capturing Asian carp, further sampling is required to fully evaluate this gear.

Project Highlights:

- No Asian carp were captured in the Great Lakes trap net in Lake Calumet over 107 net-days. The Great Lakes trap nets were effective at capturing Asian carp in the Material Services pit (Marseilles Pool) over 70 net-days.
- Surface-to-bottom gill nets caught more Asian carp than traditional gill nets per 4-hour set, whereas surface-to-bottom gill nets had similar catch rates to large mesh sinking gill nets per unit area of net.
- Standard small (1.2 m diameter) hoop nets caught more Asian carp than large (2 m) hoop nets per net night.
- Spreading soybean meal on the surface of the water did not attract Asian carp to feed.
- Recommend further sampling to refine optimal sampling protocols and efficacies, the Great Lakes trap nets represent a possible tool for long-term monitoring in standing or low-flow areas, but may represent targets for vandalism and may not be appropriate for setting in flowing water.

Water Gun Development and Testing

William Morrow, US Geological Survey – Illinois Water Science Center;
Jason (Jackson) Gross, USGS – Northern Rocky Mountain Sciences Center
Mark Gaikowski, USGS – Upper Midwest Environmental Sciences Center
and
Phillip Carpenter
Northern Illinois University

Participating Agencies: US Geological Survey – Illinois Water Science Center, Northern Rocky Mountain Sciences Center, Upper Midwest Environmental Sciences Center (co-leads); Northern Illinois University (project support).

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 may have potential as a physical deterrent to carp movement through the emission of high pressure underwater sound waves. These sound waves are produced by a pneumatic water gun that compresses water with a piston traveling through a cylinder. The resulting burst of compressed water induces cavitation in the water which generates a pulsed sound-pressure wave as these cavities collapse. The sound-pressure wave may deter or kill fish depending on proximity to the wave source. The water gun may be operated in either fixed or mobile deployments to create a barrier to deter the movement of fish. In addition to the need to assess physiological and behavioral effects of the water gun on fishes, its potential impacts on structures (e.g. canal walls) needed to be evaluated.

Establishing physical characteristics of water discharge and potential impacts on in-water structures

Determining pressure gradient during water gun operation – To answer questions from the Army Corp of Engineers Rock Island District about the expected underwater pressures exerted upon in-water structures, the USGS performed a series of tests at the USGS Upper Midwest Environmental Science Center (UMESC) in La Crosse, WI to quantify the magnitude and extent of the pressure wave produced by the water guns.

Trials were completed using the 120-in^3 and 1-in^3 water guns suspended 1.1 m below the water surface (depth at discharge port) in the middle of the UMESC 0.5 acre earthen test pond (average depth ~2.5 m). Three hydrophones were suspended beneath a buoy 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 hydrophones were positioned along a grid of 32 points arrayed around the water gun position and sound pressure recordings were collected at each point in the grid from 5 separate gun discharges. The water gun orientation was then turned 90° and the measurement repeated. The 120-in^3 gun was operated at its maximum operating pressure (2,000 PSI). The data for each measuring point was averaged and then a map was prepared that defined the pressure distribution for each of the three hydrophone depths. Additional, more robust underwater blast sensors measured the maximum PSI values approximately 4.6 m from the 120-in^3 water gun. Finally, six fixed, three-component

geophones positioned on the berm of the pond provided 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. Similar data were collected for the 1-in^3 water gun except that the number of sound recording sites was reduced by 75% (the 1-in^3 water gun has 4 ports equally distributed around the gun) and the operating pressure of the gun was lowered to 1,500 PSI (the maximum operating pressure of the current 1-in^3 water guns).

Processing of the data set is ongoing, but initial pressure distribution maps have been prepared. Modeling (3D) of the data set is 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.

Preliminary results show that the energy from the 120-in^3 and 1-in^3 water guns is distributed evenly beyond a 4.6-6.1 m high-pressure zone around the water gun. The maximum pressure recorded during operation of the 120-in^3 gun at 2,000 PSI was 47 PSI recorded at ~4.6 m from the gun discharge ports. The 120-in^3 water gun was capable of projecting a ~5 PSI blast to a distance of ~13.7 m (Figure 1) from the water gun while the 1-in^3 water gun projected a 3 PSI blast out to ~18.3 m. The 120-in^3 water gun and the 1-in^3 water gun were discharged >3,700 and >3,000 times, respectively, over the course of pressure gradient mapping and fish trials in the UMESC test pond. The loads described above were applied with no discernible effect to the earthen pond walls or concrete structures within the UMESC test pond. Portions of the walls and the concrete structures within the pond would have received blasts exceeding 8 PSI during operation of the 120-in^3 water gun.

Seismic Structural Testing
Concerns about the possible structural impacts by the USACE prevented planned testing during 2012 at the Thomas J. O'Brien Lock and Dam. To address these concerns, the USGS has 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 a "surrogate" site that approximates the conditions at the O'Brien Lock and Dam. Potential sites are being evaluated with testing planned during summer 2013. A data report covering the data collected in 2011 at the Chicago Sanitary and Ship Canal near Lemont is nearing completion.

Characterizing the response of Asian carp to water gun discharge
Field trials – Behavioral response trials were conducted in the Hanson Material Service gravel pits which form a backwater area of the Illinois River near Morris, IL. Asian carp (Bighead Carp and Silver Carp) were placed within a simulated test canal (prepared using mesh net panels suspended in the water column) then their response to water gun operation was monitored. A data report is in preparation by USGS NOROCK and collaborators.

Controlled field trials at UMESC – Behavioral responses of Silver Carp were monitored using juvenile Silver Carp in the UMESC test pond used during pressure gradient mapping. For trials using the 120-in^3 water gun, two guns were used with one gun suspended from a platform positioned on the North and South ends of the research pond. The gun firing alternated between the North and South gun when tests were conducted with the 120-in^3 guns. Tests conducted with the 1-in^3 gun were planned to replicate tests completed with the 120-in^3 gun, however, one of the

two 1-in^3 guns would not consistently discharge under the conditions used in this trial. That gun was removed from service and further tests with the 1-in^3 gun were completed with a single unit in service operating at the South gun position.

Thirty Silver Carp were placed into the test pond at least 24 h before gun operation. All Silver Carp placed into the UMESC test pond were tagged with a passive integrated transponder (PIT-tag) inserted into the abdomen >1week before placement into the test pond. Silver Carp were inventoried by PIT-tag number into and out of the test pond to ensure 100% recovery of all tested fish. Naïve fish were used in all trials (i.e. the pond was drained and all fish removed between trials) except that fish in trial 5 (second trial with the 1-in^3 water gun) remained in the pond while an additional 30 fish were added so that a total of 60 fish were present during trial 6 (the third trial with the 1-in^3 water gun). The current air compressor configuration used for water gun work only allows operation when air temperature exceeds 5°C (41°F), thus the forecasted drop in air temperature required us to conduct trial 6 sooner than anticipated and did not allow adequate time to drain and fill the test pond.

Fish movement within the test pond (Figure 2) was monitored using overhead surveillance cameras (5 lines of 6 surveillance cameras), PIT tag antennae (12 antennae arrayed in two lines of 6 antennae) and split-beam hydroacoustic transducers (four 200 kHz transducers arrayed in two lines of two). Submersible video cameras were also used on select trials to monitor fish behavior during water gun operation. After fish had been allowed to acclimate to the test pond, the 120-in^3 or 1-in^3 water gun was operated for six 30-min firing periods with interleaving 30-min "quiet" periods. The respective water gun was operated over its operational pressure range (e.g. 120-in^3 1,000-2,000 PSI; 1-in^3 1,000-1,500 PSI) in 6 even pressure increments. When a water gun was discharged, it was discharged at a rate of 6 discharges per min. Fish responses were monitored for the next ~12 h then the pond was drained and all fish inventoried out of the pond and placed into a holding tank to monitor latent mortality.

Detection and movement patterns of Silver Carp observed with hydroacoustic systems and surveillance cameras were determined. Video records for the day water guns were operated (30 min before gun operation through 30 min after gun operation; video cameras were not effective in monitoring fish movement in low light conditions) were reviewed by trained technicians and the number of fish observed and the direction of movement of fish in the video camera field of view were recorded. Randomly selected video segments were watched a second time by a different technician to determine an observer error rate; observers during the second viewing were unaware of the findings of the first viewing. Video playback was at about 4x normal speed to enhance detection. Hydroacoustic data are being processed according to standard hydroacoustic data processing techniques. Video and hydroacoustic data are being analyzed to characterize the response of Silver Carp to water gun discharge in the UMESC test pond. Video observation and hydroacoustic detections indicated that Silver Carp formed large (10+ fish) schools very quickly after placement into the test pond. The hydroacoustic signatures suggest that Silver Carp split into smaller schools during night/low light conditions and had substantially greater activity than during daylight conditions, possibly due to the high water clarity in our test pond (Figure 3).

Initial analyses suggest that water gun operation caused Silver Carp to leave the area around the water gun as evidenced by changes in detection rates by the hydroacoustic transducers. For example, during operation of the 120-in^3 water gun on 25 Oct 2012 (Figure 4), operation of the north water gun generally increased fish detection on node 2 (transducer located in the pond center) while operation of the south water gun generally increased detection at node 1. Detection of fish at node 2 was expected because it was located at the approximate midpoint of the pond in an area of relatively low pressure gradient. Fish were occasionally observed along the periphery of the pond in the vicinity of the operating gun. Though pressure gradients were not measured at the location where fish were observed, overlaying the measured pressure gradient (see above) suggests that the fish were entering an area of <6 PSI during 120-in^3 water gun operation. This pattern was confirmed in video observation of silver carp response to operation of the 120-in^3 water gun on 20 Oct 2012 (Figure 5). Preliminary analysis indicates that Silver Carp were not detected in the vicinity of the water gun during operation (e.g. in camera rows 1 & 2 when the south gun was operating or rows 4 and 5 when the north gun was operating) but returned to the area around the water gun when it was not operating. A summary report of the behavioral responses of Silver Carp is in preparation.

Recommendations: We recommend the continued use of water guns to clear fish at the electric barrier system in support of barrier maintenance operations and additional testing of this technique as a deterrent and control strategy for invasive species management. Additional seismic testing of water guns to assess effects on navigation structures, locks, and equipment should be completed. Potential structural test locations exist in the Illinois River and are being evaluated for potential use in 2013. Additional studies should also focus on defining the pressure distribution when the water guns are fired at different pressures, under synchronous and asynchronous operation of 2+ water guns and in open water environments. Additional controlled tests should be completed in the UMESC test pond to further clarify the response of Silver Carp and Bighead Carp, preferably during low light periods to maximize fish movement during testing. Additional studies should be completed to assess the response of native fishes under controlled conditions (e.g. at UMESC test ponds). Field trials should be completed to assess response of Bighead Carp and Silver Carp under unconstrained conditions. Potential locations exist near Morris, IL on the Illinois River.

Project Highlights:

- Behavioral responses of Silver Carp were characterized under controlled conditions.
- Pressure gradients around the 120-in^3 water gun were mapped.
- Investigations of the response of Silver Carp to pure and complex tones, including those of outboard motors, were initiated through collaboration with the University of Minnesota-Duluth.
- Recommend the continued use of water guns to clear fish at the electric barrier system in support of barrier maintenance operations and additional testing of this technique as a deterrent and control strategy for invasive species management.

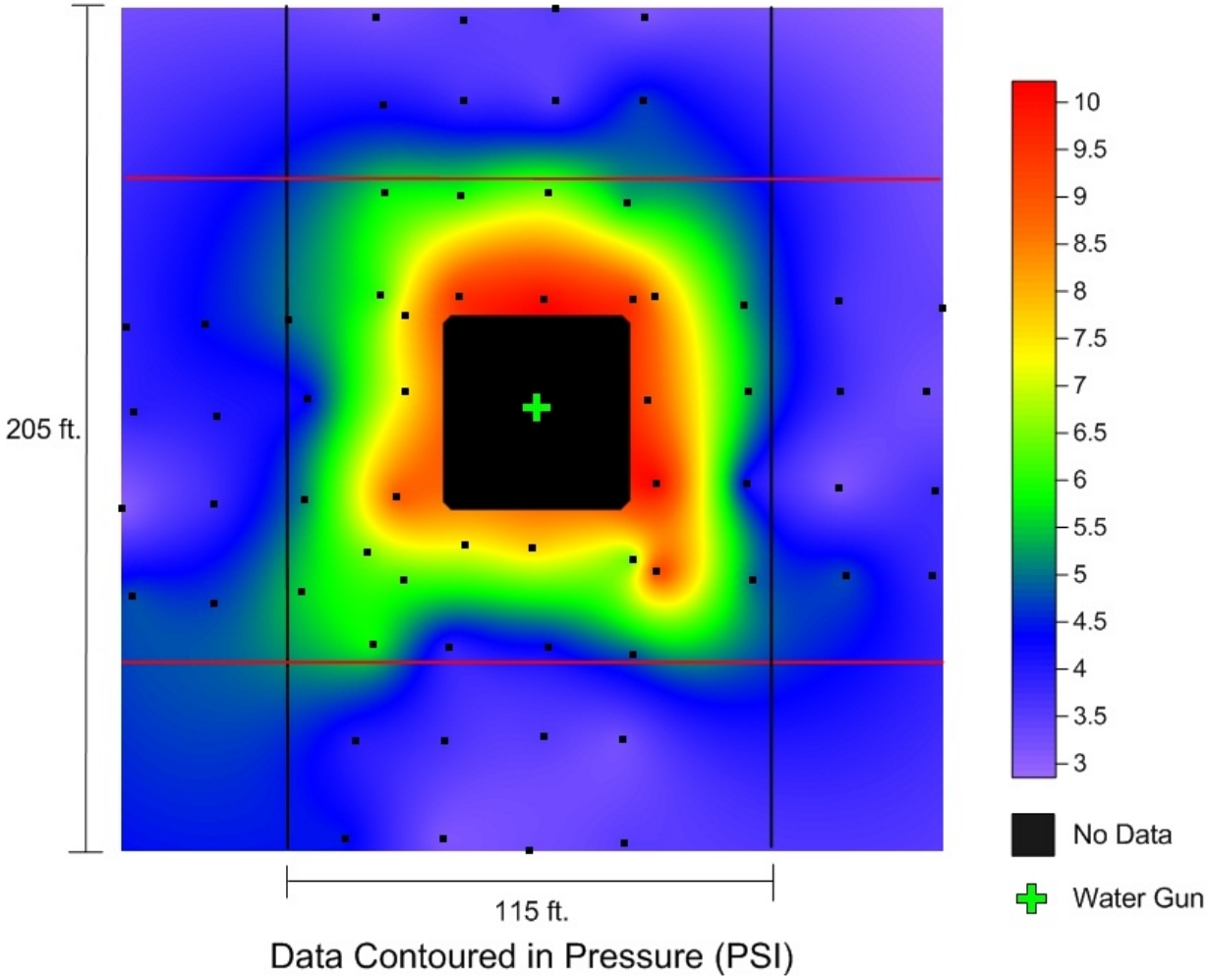

Figure 1: Pressure gradient resulting from discharge of the 120-in^3 water gun operated at 2,000 PSI. Diagram represents predicted pressure gradient at 1.1 m below the water surface.

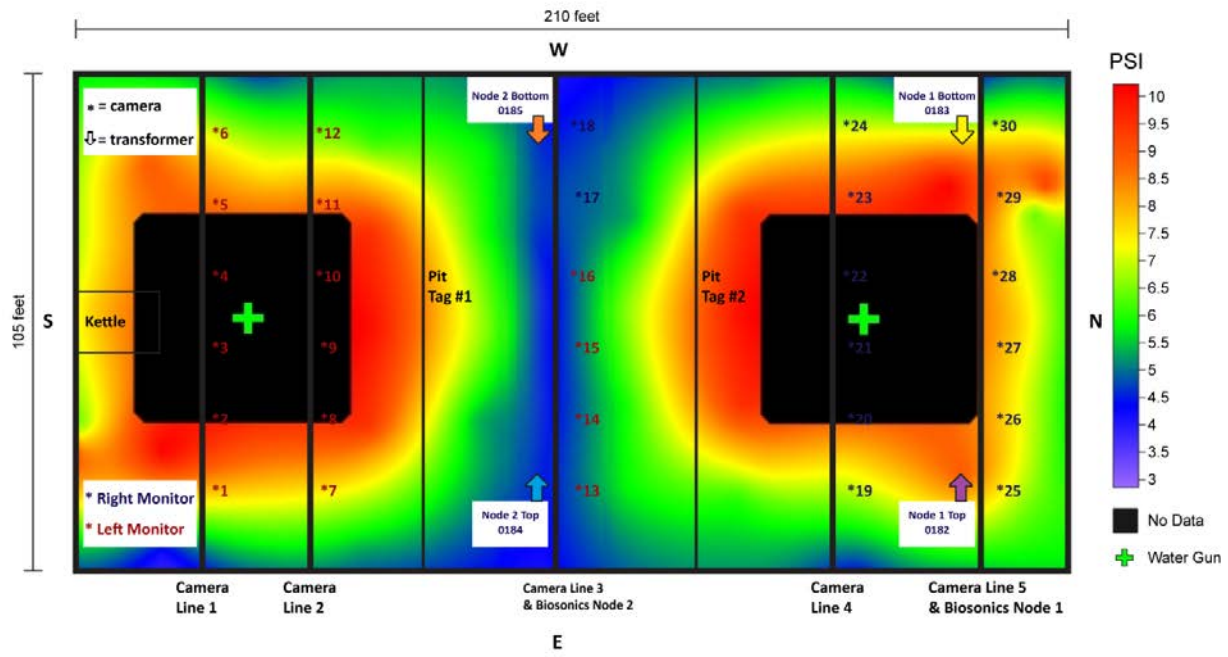

Figure 2: Test configuration in the UMESC research pond. A single 120-in^3 water gun was positioned at a depth of ~1.2 m on each end of the test pond (denoted by the green "+"). Fish movement was monitored by surveillance cameras, passive integrated transponder antennae and split-beam hydroacoustic arrays.

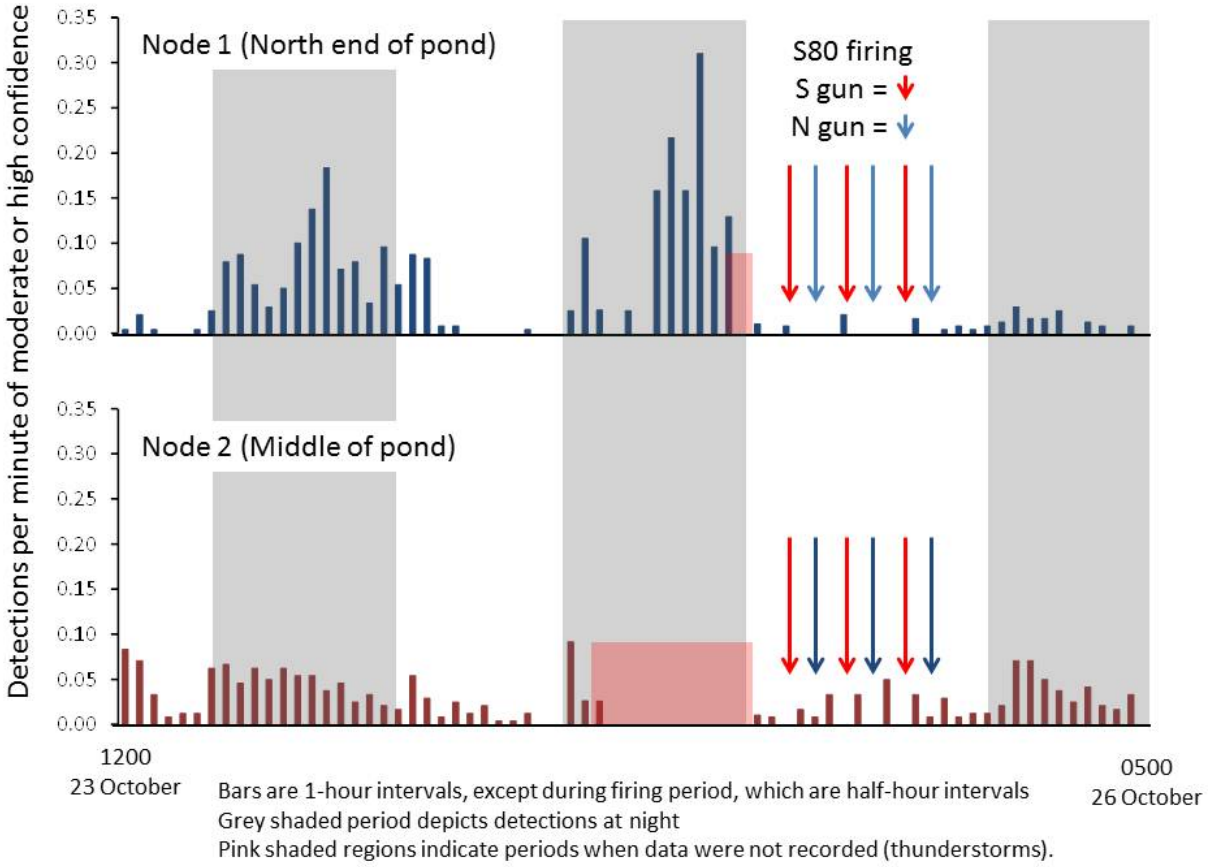

Figure 3: Silver Carp detected in split-beam hydroacoustic arrays during night and daylight conditions in the UMESC research operations.

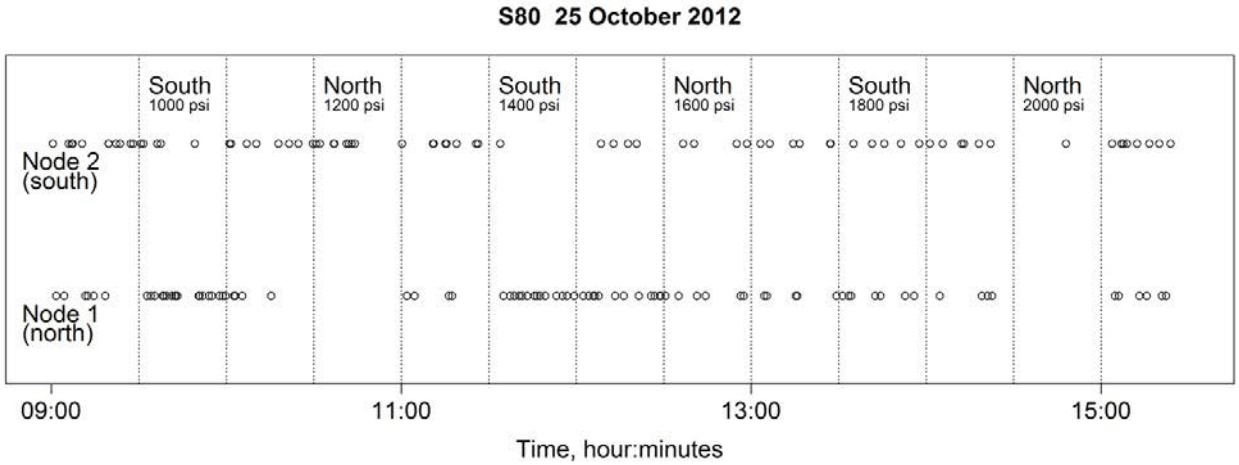

Figure 4: Detection of Silver Carp by split-beam hydroacoustic arrays before, during and after operation of the 120-in^3 water gun.

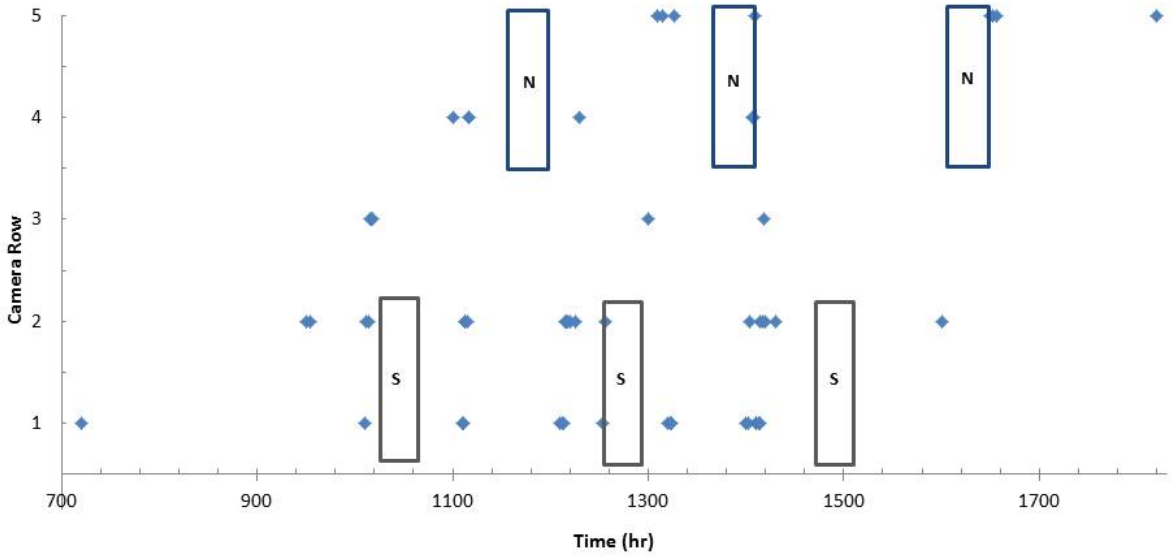

Figure 5: Detection of Silver Carp by overhead surveillance cameras before, during and after operation of the 120-in^3 water gun. Each diamond represents a visual detection of 1+ Silver Carp present in a video field of view within the assigned camera row (there were 6 video cameras per row).

Alternate Pathway Surveillance in Illinois - Law Enforcement

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

Participating Agencies: Illinois Department of Natural Resources (lead).

Introduction: Asian carp are reared in aquaculture facilities in parts of the southern United States. It is believed Asian carp are most highly valued alive at Chicago fish markets, which tempts non-compliant fish dealers to satisfy their customers. This illicit trade of live Asian carp may be a potential threat that circumvents the considerable effort to prevent movement through the CAWS.

The Lacey Act prohibits the interstate movement of live organisms that are on the list of injurious species. Currently, three species of Asian carp—Silver, Bighead, and Black—are on that list. Although the Lacey Act prohibits movement of live Asian carp across state lines, it does not prohibit Asian carp aquaculture or the possession of live Asian carp in many states. Each of the Great Lakes states and the Province of Ontario has made it illegal to possess live Asian carp within its jurisdiction. Despite the Lacey Act and state laws, the movement of live Asian carp persists. Several recent arrests at the U.S./Canadian border illustrate this disconnect between the law and observed practice. In one instance, a shipper's tanks contained live Asian carp in water. In another instance, the shipper's dewatered tanks contained Asian carp on ice; upon seizure, law enforcement officers observed moving Asian carp and placed these fish in water, where they quickly righted themselves and began swimming. In all instances, the carps originated from American fish farms outside of the Great Lakes basin. Enforcement of U.S. and Canadian laws regulating the movement of live fish is essential to prevent establishment of Asian carp in the Great Lakes basin.

Although not listed under the Lacey Act, Grass Carp are becoming widely distributed throughout the Midwest. The use of triploid Grass Carp for pond and lake aquatic vegetation control has been a well known management practice. Live Grass Carp are also a preferred food fish in live fish markets in the Chicago area. Unit recently the use of diploid Grass Carp was allowed for these live markets. Although Grass Carp have been established and reproducing in the Illinois River for several years, their distribution and impacts are unknown in the Great Lakes. To reduce the threat of further distribution into the Great Lakes the IDNR discontinued the issuing of restricted species transportation permits for diploid Grass Carp to live fish markets.

Juvenile Asian carp have been included in the live bait trade in the past and are similar in appearance to species used as bait (e.g., Gizzard Shad and Threadfin Shad), which may be inadvertently transported along with more typical bait fish species (i.e. Fathead Minnows, Golden Shiners, and White Suckers). Given that sources of many bait stocks are from regions of the United States where Bighead and Silver Carp have established populations, the possibility exists that fisherman are unintentionally distributing Asian carp throughout the Great Lakes region through contaminated bait stocks. One potential source for Asian carp presence in the CAWS is through unintentional release of Asian carp in contaminated bait stocks when

fisherman discard unused bait into rivers and streams. Other anthropogenic distribution pathways also exist, including the unintentional transport and stocking of Asian carp with introduced sport species and/or the deliberate transport of Asian carp to live fish markets and retail food establishments.

Screening of fish tanks at wholesale and retail bait supply facilities and increased enforcement activities related to fish hauling and stocking are direct approaches to evaluating alternative introduction pathways. In addition to continuing surveillance efforts at bait shops, IDNR staff and Conservation Police Officers (CPOs) plan to perform education and enforcement activities at 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.

Objectives: To create a more robust and effective enforcement component of IDNR's invasive species program, we proposed to:

1) Form the IDNR invasive species law enforcement unit.
2) Create a multi-agency invasive species task force to provide assistance and share ANS intelligence one another.
3) Increase surveillance of fish haulers stocking local water bodies, area fish production facilities, and live fish markets and food establishments;
4) Perform administrative import and export audits and inspections to ensure compliance with the federal Lacey Act and Illinois Injurious Species Rule
5) Increase checks on commercial fishers, personnel working and equipment on GLRI funded programs.
6) Continue visual inspections of fish tanks at wholesale and retail bait suppliers in the Chicago metro region

Results and Discussion: In July of 2012, an IDNR Conservation Police Invasive Species Unit (ISU) consisting of two officers was created. The ISU logged 1,035 hours investigating invasive species issues past six months.

Initially, the ISU conducted surveillance in Chicago gathering intelligence on several businesses and fish haulers. Surveillance was expanded to others areas of the state where Asian carp are being processed. Additional leads and information were obtained on fish haulers buying live Asian carp from commercial fisherman on the Illinois and Mississippi Rivers. The ISU then conducted a joint operation in Chicago with WDNR, USFWS, USDA and FDA to inspect wholesale and retail fish dealers. In additional operations with USFWS, GPS trackers were positioned on two fish hauling trucks from an Indiana live fish hauling company. One of these tracked trucks was stopped in Effingham Illinois suspected of illegally transporting live Asian carp (Bighead Carp). Information from the GPS trackers demonstrated the truck had visited several Arkansas fish farms, one farm in particular was believed to have previously produced and supplied Bighead Carp to the same fish hauling company in 2011 which was detained in Canada while crossing the border. It was found the Effingham truck was transporting live Grass Carp and Channel Catfish. Grass Carp are a restricted species which require a restricted species transportation permit and the Channel Catfish are a VHS-susceptible species which require certified health testing and importation permits. Both of these species were being transported to Chicago live markets without the proper permits. No Bighead or Silver Carp were found in this

shipment. During this investigation it was discovered that the fish hauling company had sold over $150,000 worth of live fish and turtles in 2012, most of which were transported and sold illegally. As a result of this investigation, several possible charges and penalties were filed against this fish hauling company.

The ISU investigated vandalism that occurred to Asian carp research equipment supported by GLRI at Lake Calumet. Although suspects were identified and interview, no formal charges could be filed. Other invasive species investigations revealed the selling of live rusty crayfish from an Illinois bait shop. ISU and other IDNR CPO's cited several subjects for possessing over 100 live rusty crayfish in the Chicago area. The ISU investigated the illegal selling of native turtles on the internet for pet trade. A seller is required to have either a resident or nonresident aquatic life dealer's license and the native turtles must be of proper size. The ISU conducted a covert operation in which an undercover officer purchased two pounds of wild Chinook (King) Salmon. As a result of this investigation, the offender was charged and fined.

In December, an Asian Carp Task Force was formed and met in Chicago. In attendance were law enforcement officials from USFWS, Missouri DNR, Wisconsin DNR, Minnesota DNR, Michigan DNR, Indiana DNR, and Ohio DNR. The purpose of this task force meeting was to share invasive species information and intelligence for each state and plan future cooperative investigations.

Recommendations: We recommend increased surveillance of fish haulers stocking local water bodies, area fish production facilities, and especially live fish markets. We recommend food establishments obtain information on the risk of alternative distribution pathways and prevent illegal importation of live Asian carp. Continued surveillance of the bait trade in the Chicago metropolitan area by focusing enforcement activities on wholesale bait dealers is necessary. Conducting regular inspections of the three area bait wholesalers should be more economical and efficient than monitoring individual bait stores. We suggest informational packets be distributed or made readily available to aquaculturist, aquatic life dealers, bait shops, and fish importers with VHS-susceptible and salmonid importation, restricted species transportation, and reptile administrative rules. The ISU and USFWS would like to educate CPO's and ISP with the interdiction of illegal fish haulers.

Project Highlights:

- Invasive species law enforcement unit was formed.
- ISU logged 1,035 hours investigating invasive species issues.
- ISU gained much intelligence from Chicago operations.
- Conducted a joint investigation with USFWS in which several charges and penalties were given to an Indiana fish hauler.
- A multi-agency Asian carp task force was formed to share intelligence, information, and plan future operations.
- Recommend increased surveillance of fish haulers stocking local water bodies, area fish production facilities, and especially live fish markets with continued surveillance of the bait trade in the Chicago metropolitan area.

Alternative Pathway Surveillance in Illinois – Urban Pond Monitoring

Tristan Widloe, Victor Santucci, David Wyffels, Michael McClelland, Brennan Caputo, Matthew O'Hara, and Kevin Irons; Illinois Department of Natural Resources

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

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 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 or Silver Carp are captured during sampling responses. However, this pattern changed in 2011 when 20 very large 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. There were 21 urban fishing lakes in the program, six of which had verified captures of Bighead Carp either from sampling, pond rehabilitation with piscicide, or natural die offs; two had reported sightings of Asian carp that were not confirmed by sampling (Table 1). The distance from urban fishing ponds to Lake Michigan ranged from 0.1-25.7 miles. The distance from ponds to Chicago Area Waterway System (CAWS) waterways upstream of the electric barrier system ranged from 0.01-5.1 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 barrier system (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 ranged from 3-19.5 miles. The distance from ponds to Chicago Area Waterway System (CAWS) waterways upstream of the electric barrier system ranged from 0.03-2.7 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 guano of piscivorous birds?), they should be examined for the presence of live Asian carp given their proximity to the CAWS.

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 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	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, none sampled	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	5.0	0.2-LCALR	None
Lake Owens	Cook	Hazelcrest	NR	12.2	4.8-LCALR	None
Cermak Quarry	Cook	Lyons	None sampled	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

Objective: The 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: Electrofishing and trammel/gill nets were used to sample urban fishing ponds in 2012. All boat electrofishing used pulsed-DC current and most samples were taken with two dip netters. Trammel and gill nets were typically 10 feet deep x 300 feet long in bar mesh sizes ranging from 3.5-4.5 inches. Electrofishing runs were generally 15-minutes in length. The goal

was to sample the entire pond using electrofishing, which included both shoreline and open water habitats. Therefore, total electrofishing time varied for each pond. Net sets included driving fish into the nets with noise (i.e., "pounding" banging on boat hulls, or racing tipped up motors) and electrofishing. 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 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	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: Nineteen Chicago area ponds were sampled in 2012 with an estimated 727 person-hours spent on sampling (Table 3). Jackson Park lagoon, due to its size and connectivity to Lake Michigan, was sampled twice. Effort for all ponds was 30 hours of electrofishing (96 transects) and 6.2 miles of trammel/gill net (55 sets). We sampled a total of 9,103 fish representing 29 species and 2 hybrid groups (Table 4). Bluegill, Gizzard Shad, Common Carp, Largemouth Bass and Goldfish were the numerically dominant species making up 82% of all fish sampled. In addition, we examined 1,666 YOY Gizzard Shad and found no Asian carp YOY. A total of six Bighead Carp were removed from three ponds (Humboldt Park, Garfield Park, and Joe's Pond). Three Bighead Carp were removed from Humboldt Park with weights of 62, 34 and 46 pounds. Two Bighead Carp were captured and removed from Garfield Park weighing 53 and 46 pounds. One Bighead Carp was removed from Joe's Pond with a weight of 34 pounds. These fish had a mean length of 44 inches. The three Bighead Carp from Humboldt Park were kept alive and are currently on exhibit at the John G. Shedd Aquarium.

The source of Bighead Carp in urban fishing ponds has not been confirmed to date and identifying a specific source may prove impossible. However, there is building evidence 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 very large fish of similar size 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).

Recommendations: We recommend additional sampling of ponds that Asian carp were collected from to ensure that no Asian carp remain. We also recommend repeat sampling of ponds that had positive detections for Asian carp eDNA with Powderhorn Lake being the highest priority as it was not sampled in 2012.

Project Highlights:

- Sampled 19 ponds with electrofishing and trammel/gill nets during 2012.
- Estimated 727 person-hours were spent to complete 30 hours of electrofishing and set 6.2 miles of trammel/gill net.
- Sampled 9,103 fish representing 29 species and 2 hybrid groups.
- Six Bighead Carp were removed from three ponds (Garfield Park, Humboldt Park, Joe's Pond); three are on exhibit at the John G. Shedd Aquarium.
- Recommend additional sampling of ponds from which Bighead Carp were removed, as well as repeat sampling of ponds yielding positive results for Asian carp eDNA.

Table 3. Summary effort and catch data for urban pond monitoring 24 May – 2 November 2012.

		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*)
Garfield Park (24 May 2012)								
Electrofishing	17	5 transects	3.6 hours	0	0	0	0	0
Trammel/gill nets	17	2 net sets	0.1 miles	2	1	0	2	0
Harborside Golf Course Lake (13 August 2012)								
Electrofishing	25.5	11 transects	2.75 hours	718	15	1	0	0
Trammel/gill nets	25.5	4 net sets	0.9 miles	97	7	1	0	0
Saganashkee Slough (23 August 2012)								
Electrofishing	25.5	8 transects	2 hours	697	11	0	0	0
Trammel/gill nets	25.5	4 net sets	0.6 miles	18	4	0	0	0
Community Park (4 September 2012)								
Electrofishing	25.5	2 transects	0.5 hours	595	6	0	0	0
Trammel/gill nets	25.5	2 net sets	0.1 miles	3	2	0	0	0
Commissioners Park (5 September 2012)								
Electrofishing	25.5	2 transects	0.5 hours	134	5	1	0	0
Trammel/gill nets	25.5	1 net set	0.1 miles	4	1	0	0	0
Lake Owens (6 September 2012)								
Electrofishing	17	4 tranects	1 hour	216	4	1	0	0
Trammel/gill nets	17	1 net set	0.3 miles	3	2	0	0	0
Columbus Park (1 October 2012)								
Electrofishing	8.5	3 transects	0.75 hours	86	5	1	0	0
Trammel/gill nets	8.5	2 net sets	0.1 miles	1	1	0	0	0
McKinley Park (1 October 2012)								
Electrofishing	8.5	4 transects	1 hour	172	7	1	0	0
Trammel/gill nets	8.5	1 net set	0.3 miles	1	1	0	0	0
Sherman Park (2 October 2012)								
Electrofishing	25.5	4 transects	1 hour	206	6	0	0	0
Trammel/gill nets	25.5	4 net sets	0.3 miles	0	0	0	0	0
Marquette Park (3 October 2012)								
Electrofishing	25.5	5 transects	1.25 hours	96	10	1	0	0
Trammel/gill nets	25.5	3 net sets	0.4 miles	0	0	0	0	0
Douglas Park (4 October 2012)								
Electrofishing	17	3 transects	0.75 hours	36	6	0	0	0
Trammel/gill nets	25.5	2 net sets	0.2 miles	1	1	0	0	0

Table 3. Continued.

Operation (date) and Gear	Estimated person-hours	Sample Effort: Samples (*N*)	Sample Effort: Total effort	Catch: All fish (*N*)	Catch: Species (*N*)	Catch: Hybrids (*N*)	Catch: Bighead carp (*N*)	Catch: Silver carp (*N*)
Humboldt Park (9 October 2012)								
Electrofishing	12.75	5 transects	1.25 hours	639	9	1	0	0
Trammel/gill nets	12.75	2 net sets	0.2 miles	50	4	0	3	0
Riis Park (9 October 12)								
Electrofishing	12.75	1 transect	0.2 hours	121	5	1	0	0
Jackson Park (10 October 2012)								
Electrofishing	12.75	8 transects	2 hours	952	13	1	0	0
Trammel/gill nets	8.5	3 net sets	0.3 miles	49	3	0	0	0
Joe's Pond (10 October 2012)								
Electrofishing	12.75	2 transects	0.5 hours	239	4	0	0	0
Trammel/gill nets	8.5	3 net sets	0.3 miles	11	5	0	1	0
Washington Park (11 October 2012)								
Electrofishing	12.75	6 transects	1.5 hours	593	11	0	0	0
Trammel/gill nets	12.75	4 net sets	0.3 miles	3	1	0	0	0
Horsetail Lake (11 October 2012)								
Electrofishing	12.75	4 transects	1 hours	349	5	0	0	0
Trammel/gill nets	12.75	3 net sets	0.3 miles	0	0	0	0	0
Tampier Lake (17 October 2012)								
Electrofishing	42.5	13 transects	5.5 hours	1,801	12	0	0	0
Trammel/gill nets	17	7 net sets	0.6 miles	74	5	0	0	0
Jackson Park (1 November 2012)								
Electrofishing	17	4 transects	2.25 hours	1,026	14	0	0	0
Trammel/gill nets	25.5	4 net sets	0.5 miles	45	6	0	0	0
Sag Quarry West (2 November 2012)								
Electrofishing	17	2 transects	0.6 hrs	50	7	0	0	0
Trammel/gill nets	25.5	3 net sets	0.3 miles	15	4	0	0	0

Table 4. Total number and percentage of fish sampled by electrofishing and trammel/gill nets during urban pond monitoring in 2012.

Species	*N*	Percent
Bluegill	2,633	28.9%
Gizzard shad < 6 in.	1,666	18.3%
Gizzard shad > 6 in.	1,209	13.3%
Common carp	1,035	11.4%
Largemouth bass	627	6.9%
Goldfish	336	3.7%
Black bullhead	295	3.2%
Black crappie	272	3.0%
Green sunfish	206	2.3%
Sunfish hybrid	124	1.4%
White crappie	104	1.1%
Fathead minnow	93	1.0%
Yellow bullhead	76	0.8%
Yellow bass	73	0.8%
Pumpkinseed	60	0.7%
Golden shiner	52	0.6%
Warmouth	47	0.5%
Channel catfish	42	0.5%
White perch	39	0.4%
Brown bullhead	34	0.4%
Black buffalo	20	0.2%
Grass carp	12	0.1%
Freshwater drum	11	0.1%
Bluntnose minnow	10	0.1%
Bighead carp	6	0.1%
Bullhead minnow	6	0.1%
Walleye	6	0.1%
Carp x goldfish hybrid	2	<0.1%
Orangespotted sunfish	2	<0.1%
Redear sunfish	2	<0.1%
White bass	2	<0.1%
Blackstripe topminnow	1	<0.1%
All species	9,103	100%
Species (*N*)	29	
Hybrids (*N*)	2	

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Appendix A. Participants of the Monitoring and Rapid Response Workgroup, Including Their Roles and Affiliations, in 2012.

Co Chairs
John Rogner, Assistant Director, Illinois Department of Natural Resources
John Dettmers, Senior Fishery Biologist, Great Lakes Fishery Commission

Agency Representatives
Vic Santucci, IDNR
Kevin Irons, IDNR
Kelly Baerwaldt, USACE
Sam Finney, USFWS

Independent Technical Experts
Scudder Mackey, Habitat Solutions NA/University of Windsor
Irwin Polls, Ecological Monitoring and Associates
Phil Moy, Wisconsin Sea Grant
Duane Chapman, US Geological Survey
John Epifanio, University of Illinois

Agency Participants
Matt Shanks, USACE
Felicia Kirksey, USACE
Shawna Herleth-King, USACE
Chuck Shea, USACE
Mark Cornish, USACE
Doug Keller, Indiana DNR
Mike McClelland, IDNR
Matt O'Hara, IDNR
Jim Mick, IDNR
Steve Pescitelli, IDNR
Rob Maher, IDNR
Dan Sallee, IDNR
Steve Shults, IDNR
Rob Sulski, ILEPA
Rob Simmonds, USFWS
Tracy Hill, USFWS
Pam Thiel, USFWS
Mike Hoff, USFWS
Aaron Woldt, USFWS
Jeff Stewart, USFWS
Janet Pellegrini, USEPA

Appendix B. Population Status of Asian Carp in the Illinois River in 2012: Implications of Harvest and Other Control Strategies.

Annual Report to the

Illinois Department of Natural Resources

February 2013

Prepared By:

Jim Garvey, David Glover, Marybeth Brey, Greg Whitledge, and Wes Bouska

Center for Fisheries, Aquaculture, and Aquatic Sciences

Southern Illinois University Carbondale

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

Introduction: Asian carp of the genus *Hypophthalmichthys* became abundant in the Illinois River in the early 2000s (Chick and Pegg 2001). As of 2013, they have invaded Dresden Pool and have reached apparently high densities in Marseilles Pool (about 80 miles downstream of Lake Michigan). Although present, they do not appear to have reproduced in the upper river. These two reaches are below the electric barrier system emplaced in the Chicago Sanitary and Ship Canal (CSSC). If Asian carp do move upstream and the electric barrier system fails, these fishes threaten to invade the Chicago Area Waterway System (CAWS) and Lake Michigan. Populations of Asian carp have become established with apparent reproduction occurring in the river below the Starved Rock Lock and Dam (L&D), which is comprised of the Peoria, LaGrange, and Alton reaches. Asian carp are a clear nuisance in these areas and likely negatively affect the local ecosystems and economies.

The goal of this research is to evaluate the impact of two potentially complementary control efforts that are occurring in the Illinois River. Currently, removal by fishing is the only efficacious control method. In reaches above Starved Rock L&D, contracted fishing is occurring to reduce the numbers of adult Asian carp that may swim to the electric barrier system and challenge it. These fishes also may build populations in Dresden and Lockport reaches. In reaches below Starved Rock L&D, privately supported commercial fishing occurs for Asian carp, although the effort varies depending on market demand, fish condition, fish abundance, and river conditions.

Asian carp populations that are in proximity to the electric barrier system within the CSSC likely originate from the lower river below Starved Rock L&D. The highest density of Asian carp in this area is in a quarry (Hanson Material Service Corporation pits) adjacent to the river in Marseilles Pool. Our research group quantified Asian carp densities in this area during 2011, finding that densities declined from 300,000 to 198,000 fish, likely as a function of contracted fishing and emigration. Research in 2012 was aimed at determining the relative impact of fishing, emigration, and immigration on Asian carp densities in this important location near the barrier.

Methods: In 2011, we conducted the first comprehensive density and biomass estimate of the Illinois River fish assemblage using a combination of trammel netting, electrofishing, and split-beam hydroacoustics. This allowed us to set a baseline by which changes in Asian carp density and assemblage structure could be compared to control efforts and environmental conditions. Hydroacoustics, which allows us to generate a density and biomass estimate for the river, was restricted to the main channel. Greater than 2,100 miles of transects were completed. Density of Asian carp below Starved Rock L&D to the Mississippi River confluence was conservatively estimated at 743,000 individuals, comprising 1,400 tons. Asian carp dominated fish biomass, comprising more than 60% of the biomass. Our estimate was clearly conservative. Fish avoided

the survey boat. The acoustics beam was only down-looking, missing shallow areas of the river such as side channels and off-channel areas. We considered this a learning experience and opportunity to improve our sampling techniques for 2012. Data collected during 2012 that are currently being processed will allow us to "correct" our 2011 estimates to reflect a more accurate density in the main channel.

Past research conducted by our group and others has established that Asian carp are capable of moving long distances, often during a very short time (> 200 miles/month). Key to any control effort that reduces risk of Asian carp breaching the electric barrier is an understanding of the immigration rates of Asian carp from downstream "sources". In 2011 we found that immigration of Asian carp into the Illinois River from the Mississippi River is triggered by flooding. Tagged carp moved as far north as Peoria Pool; about 25% were found moving back downstream. What factors influence whether an individual remains upstream or leaves is unknown. How fish interact with lock and dam structures throughout the river, particularly at Starved Rock L&D and structures upstream is not understood. These areas may serve as attractants downstream (e.g., high densities of Asian carp occur below Starved Rock L&D) but as barriers to upstream movement. Research in 2012 began to address these issues by assessing how fishing and environmental factors such as elevated discharge affect movement toward the CAWS.

For harvest or any control effort to suppress adults from moving upstream and for the contributing populations to shrink, a host of complex, interacting factors must come to play. A simple demographics model based on limited data for Asian carp was developed in 2011. This model suggested that control at all life stages was necessary to reduce the population in the Illinois River. Although a useful first step, a predictive model needs refinement. Foremost, how population characteristics (e.g., density, age structure, size structure, growth) affect movement of Asian carp toward the electric barrier system in the CSSC need to be quantified and incorporated in a spatially explicit fashion. Demographics data from 2011 showed that each pool of the Illinois River contains populations of Silver and Bighead Carp with unique demographic characteristics. Patterns of harvest vary across these reaches, leading to complex population responses. Recruitment of Asian carp is variable. Multiple years of poor recruitment coupled with harvest or other control measures may greatly reduce population density (e.g., Lohmeyer and Garvey 2009). Harvest and other control efforts that target the reproductively active individuals in the population (i.e., large females) may suppress population growth.

Results and Discussion: This report summarizes preliminary results of research conducted in 2012 in response to 2011 findings. Our approaches were complementary but broad. We assisted state and federal agencies in detecting potential Asian carp within the electric barrier system during routine maintenance and unexpected outages. Changes in Asian carp density on a daily basis as well as through the year were quantified at the "leading edge" of the upstream Silver and Bighead Carp populations in Marseilles Pool. We worked closely with contracted commercial fishermen in this area to evaluate the efficacy of harvest as a control method. In the river below Starved Rock L&D, we orchestrated harvest of three-million pounds of Asian carp in spring 2012. These fish were converted to fish meal to be used in feeding trials for fish and livestock. Density and demographic changes as well as potential modifications in upstream movement of telemetered Asian carp were quantified. Hydroacoustic surveys with down- and side-looking transducers were conducted across > 2,300 miles of river. Otolith microchemistry was used to

determine origin of Asian carp. Unlike 2011, 2012 was a year of low discharge in the Illinois River. Our hydroacoustic assessment of the electric barrier system during clearing operations covered > 97% of the channel; fish identified with the gear were confirmed with other techniques. Harvest in 2012 removed > 19,000 Asian carp from the quarry adjacent to Marseilles Pool. Asian carp tagged in the area declined, but new Asian carp appeared to migrate into the area from the pool and perhaps from downstream reaches. Removal of Asian carp from the lower Illinois River was completed by June 2012, with a commensurate decline in catch rates of these fishes during standardized sampling. Sex ratio was skewed toward 17% more males than females. Movement of Asian carp among pools was limited in 2012, with downstream movement only occurring for 14 fish and with no apparent upstream movement. Microchemistry suggests that up to 61% of silver carp were produced in the Illinois River, whereas up to 97% of bighead carp originated there.

Population dynamics within the Illinois River and their implications are becoming clearer:

- Upstream movement of Asian carp is linked to flooding; limited discharge in the upper river may reduce the propensity for Asian carp to move en masse upstream toward the electric barrier system. This still needs to be further tested with telemetered fish across years of low and high discharge in the upper river.
- Large populations of Bighead and Silver Carp remain in Marseilles Pool of the upper river, associated with the adjacent quarry. Movement between the river channel and the quarry is frequent. Movement out of the quarry may be linked to contracted fishing occurring there.
- Contracted fishing in Marseilles reach does cause a decline in Asian carp. However, immigration of new fish is apparently high, offsetting this control effort.
- Asian carp in the upper river originate from the lower river or other rivers, particularly the Middle Mississippi River.
- Experimental harvest in the lower river (i.e., below Starved Rock L&D) coupled with poor recruitment reduced Asian carp densities. This should reduce the number of fish invading the upper river.
- Without economic incentives, commercial harvest in the lower river will remain low and control of Asian carp in the upper river (about Starved Rock L&D) will depend on the amount of government-sponsored fishing plus the reliability of the barrier system.

Project Highlights:

- Side-scan SONAR plus split-beam hydroacoustics was effective for evaluating the presence of fish > 12 inches in length in the electric barrier system. This monitoring system was deployed nine times in 2012.
- In Marseilles Pool, 279 Bighead Carp and 34 Silver Carp were tagged externally. Forty-nine percent of these fish were recaptured in 2012.
- Retrieval of tagged Asian carp showed us that contracted harvest caused 79% mortality in the quarry adjacent to Marseilles Pool.
- Frequency of the decline of tagged fish relative to untagged fish showed that immigration into the quarry offset removal of harvested fish during summer.
- Telemetry and acoustics showed that Asian carp in the quarry frequently move into the main channel and back.

- In spring 2012, 3,000,000 pounds of Asian carp were removed from Peoria, LaGrange, and Alton pools of the lower Illinois River.
- Sampling with electrofishing and trammel netting in late summer 2012 showed a decline in catch rates of Silver Carp by 33% in the lower river.
- Sex ratio of Asian carp shifted toward 17% more males than females.
- Analysis of age structure revealed that very little recruitment of Asian carp occurred in 2010 and perhaps 2011.
- Samples of fish putatively identified as "pure" Silver Carp, "pure" Bighead Carp, and hybrids were sent to Western Illinois University for analysis Pure Bighead and Silver Carp comprised 50.76% of genetic samples (hybrids=49.24%).
- Hydroacoustics combining down-looking and side-looking transects were completed in the river, comprising 2,306 miles of data collection. Analysis is ongoing. Habitat covered included 82.6% main channel, 5.2% backwater lakes, 5.1 % contiguous lakes, 4.9% side channels, 1.5% tributaries, and 0.4% harbors.
- A network of 30 stationary acoustic receivers for detecting tagged fish is now in place in the Illinois River (not including those receivers maintained by other research groups). Receivers were also placed in all lock chambers in early 2013.
- Three-hundred and seventy-two Asian carp were implanted with acoustic tags by fall 2012.
- Stationary receivers have made about 250,000 detections of tagged Asian carp by fall 2012. One-hundred fifty-seven Asian carp were located. At least seventeen Asian carp with transmitters were removed by harvest.
- In the upper river, no upstream movement of Asian carp was detected. Movement within pools was frequent.
- Elemental composition of Asian carp otoliths provided an environmental history. Up to 40% of Silver Carp in the Illinois River were produced outside the river, likely in the Middle Mississippi River. Conversely, only 3% of Bighead Carp were derived from outside the Illinois River.

Next Steps:

- Continue assisting IDNR and other agencies with assessing electric barrier system status during maintenance and unexpected outages.
- Work with USFWS to develop acoustic target strength relationships for Asian carp.
- Complete processing of hydroacoustics data from the upper and lower Illinois River in 2012 to provide a comprehensive density and biomass estimate of Asian carp. Use this estimate to "correct" the data collected in 2011.
- Continue to quantify effectiveness of the clearing efforts in the upper river.
- Assess patterns of migration in the Illinois River between the upper and lower river, focusing on the rates of immigration into the upper river, pathways of immigration (e.g., lock chambers or gates), harvest intensity, timing, and environmental conditions.
- Hold research summit with modelers to develop a comprehensive, spatially explicit model of population viability and dispersal in the Illinois River and other river reaches.

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Chapter 1:

Remote Sensing Transects at the Barrier

David C. Glover and James E. Garvey; Southern Illinois University at Carbondale

Participating Agencies: Southern Illinois University at Carbondale (lead); Illinois Department of Natural Resources, US Army Corps of Engineers – Chicago District, US Fish and Wildlife Service – Carterville Fish and Wildlife Conservation Office (field support); US Coast Guard (waterway closures); Metropolitan Water Reclamation District of Great Chicago (waterway flow management and access).

Introduction: The US Army Corp of Engineers (USACE) operates three electric aquatic invasive species dispersal barriers within the Chicago Sanitary and Ship Canal (CSSC) that must undergo periodic maintenance, which required the barrier in need of service to be powered down. In addition, occasional power outages occur. The Illinois Department of Natural Resources (IDNR) supports these maintenance operations and outages by providing fish suppression techniques if fish clearing operations are warranted by the presence of large fish. To determine whether fish suppression techniques are necessary within the electric barrier system, there is a need for rapid scans of the electric barrier system area that cover a large portion of the water column to detect the presence/absence of fish. These scans are also required to evaluate fish suppression efficacy and to provide real-time locations of fish targets within the electric barrier system to facilitate fish removal efforts. Southern Illinois University at Carbondale (SIUC) uses two remote sensing gears to determine the presence/absence of fish ≥ 12-inches TL within the electric barrier system, which represents a conservative estimate for the size of Asian carp (*Hypophthalmichthys* sp.) that may be present based on numerous years of monitoring of the population front of Asian carp by the IDNR.

Objectives: SIUC will work with state, federal, and local partners to:

1) Determine the presence/absence of fish ≥ 12-inches TL in support of regularly scheduled maintenance by the USACE, following power outages at the electric barrier system, and to evaluate the success of clearing operations;
2) Provide location specific information of detected fish targets ≥ 12-inches TL to facilitate removal of all fish over this size threshold.

Materials and Methods: SIUC conducted a total of 23 remote-sensing surveys across 9 dates in 2012 to determine the presence/absence of fish ≥ 12-inches TL in support of regularly scheduled maintenance by the USACE, following power outages at the electric barrier sytem, to provide real-time location of detected fish targets to facilitate targeted fish removal, and to evaluate the success of clearing operations. Each survey consisted of three transects conducted parallel to the side walls of the Chicago Sanitary and Ship Canal (CSSC) using a combination of split-beam hydroacoustics and side-scan SONAR for an estimated 97.6% cumulative coverage of the entire water column. Split-beam hydroacoustics was carried out using two 200 kHz multiplexed BioSonics, Inc. transducers (~7° split) mounted 15 cm below the surface in a side-looking aspect; each transducer was set to 5 ping/s with a 0.40 ms pulse duration and data was collected from 0 to 50 m. Acoustic transducers were offset in angle to maximize coverage across the

CSSC. A 1,200 kHz Marine Sonics HDS side-scan SONAR tow fish (40° beam angle in either direction with a 10° offset from 90°) was towed at 1-m depth to detect and measure potential fish targets as well as to provide detailed imagery of the electric barrier system simultaneously with data collection from split-beam hydroacoustics.

Prior to each survey, hydroacoustic transducers were calibrated on-axis with a 200 kHz tungsten carbide sphere following Foote et al. (1987). Temperature was recorded and input into Visual Acquisition 6 (BioSonics, Inc.) 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.

Data analysis: At the conclusion of each survey, remote sensing data were immediately analyzed to determine the number, location, depth, and size (TL) of potential fish targets. Side-scan SONAR and split-beam acoustics data were analyzed using Sea Scan Survey 2.3 and EchoView 5.0, respectively. Side-scan SONAR data were inspected visually and potential fish targets measured to the nearest 1-mm TL. Waypoints and depth of potential fish ≥ 12-inches TL were relayed to the US Fish and Wildlife Service (USFWS) to inspect the targets with a DIDSON camera or to the IDNR, USFWS, and USACE to target for removal during fish suppression operations. Data collected from the upper split-beam transducer was analyzed 1 m from the transducer to 0.63 m away from the side wall on the opposite side of the CSSC to account for the near-field distance (Simmonds and MacLennan 2005) and dead-zone (Ona and Mitson 1996), respectively; data from lower transducer was analyzed from 1 m to the point at which the beam intersected the bottom of the canal, parasitic structures, or low-field electrical arrays. Potential fish targets were determined using the split-beam single target detection algorithm (method 2) in EchoView 5.0 following recommended criteria from Parker-Stetter et al. (2009). Size of potential fish targets was determined using the relationship between maximum side-aspect target strength (TS) and TL ($TL = 10^{[(TS + 62.5) / 22.8]}$; Love 1971). As mentioned previously, detection of fish ≥ 12-inches TL was the primary objective of these evaluations as a conservative estimate for the size of Asian carp that may be present. Therefore, compensated-TS values corresponding to smaller sizes were omitted from the analyses.

Results and Discussion:

- March 21, 2012: Two remote sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2A in support of regularly scheduled maintenance of the electric barrier system by the USACE. No fish ≥12-inches TL were detected in either survey.
- May 3, 2012: Two remote sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2A within 24 hours of a power outage at the electric barrier system. Results indicated that there were a minimum of four fish ≥12-inches TL present between Barrier 2A and Barrier 1.
- May 9, 2012: Two remote sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2A following two draw-downs of the waterway by the MWRD at Lockport in response to local thunder storms (i.e., May 4 and 7, 2012); the USGS Water Science Center provided data indicating that the draw-downs created velocities at Lemont >2.5 – 3.0 feet per second for several hours, which had the potential

to flush fish in or out of the barrier. Results indicated that at least 7 fish ≥12-inches TL were present between Barrier 1 and Barrier 2A.

- May 12, 2012: A clearing event with water guns (one boat with two 120-cubic inch S80 guns) took place between Barrier 1 and the high-field electric array of Barrier 2A on May 12. Two initial remote sensing surveys (prior to water gun deployment) indicated the presence of a minimum of 8 fish ≥12-inches TL within this area. A single remote sensing survey was conducted after a two-hour water gun deployment; at least four fish ≥12 inches TL were identified in the target area. About 20 additional minutes of water gun operation took place in the area where fish were located (northeast corner of the target area) in an effort to kill surviving fish.
- May 22, 2012: Two remote sensing surveys between Barrier 1 and the high-field electric array of Barrier 2A were conducted to reassess the presence/absence of fish following the previous fish clearing event on May 12. A total of seven fish ≥12-inches TL were identified from each survey, suggesting that the single-boat water gun clearing operation that occurred on May 12, 2012 cleared only one fish from the target area.
- June 12, 2012: In support of clearing operations at the electric barrier system, a total of five remote-sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2B. Two surveys were conducted prior to any fish clearing actions, during which a total of 10 potential fish targets ≥12 inches TL were identified and the location relayed to boat electrofishing operators (USFWS and USACE) and IDNR personnel deploying a stationary surface-to-bottom gill net developed by a MRRWG multiagency gear development group. Most of the large-sized fish targets identified by multiple remote sensing surveys in the barrier area were captured in the gill net (7 of 10 identified targets >12 inches long captured), all of which were Common Carp and were removed from the waterway. The three remaining targets were again identified along the West wall of the CSSC in the two remote sensing surveys following this clearing action and were confirmed with USFWS DIDSON surveys. Another clearing action was initiated to capture the remaining targets, though none were captured. A final remote sensing operation in combination with USFWS DIDSON surveys confirmed that the three fish targets ≥12 inches TL were still present within the electric barrier system.
- July 17, 2012: Two remote sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2B following a power outage at the electric barrier system. No fish targets ≥ 12 inches TL were identified with split-beam acoustics or side-scan SONAR during either survey.
- September 26, 2012: A single remote sensing survey was conducted between Barrier 1 and the high-field electric array of Barrier 2A. A total of 9 fish targets over 12 inches TL were identified, ranging from 12.4-28.9 inches TL. An additional survey was conducted downstream of the electric barrier system from Barrier 2A extending to the area underneath the Romeo Road Bridge. Only two fish targets over 12 inches TL were identified (estimated length = 16 and 19 inches) suggesting that large congregations of fish were not staging en mass immediately below the electric barrier system at the time of this survey.

- November 14, 2012: Four remote sensing surveys were conducted between Barrier 1 and the high-field electric array of Barrier 2B; one survey was conducted prior to any fish clearing actions to facilitate targeted electrofishing, one survey following the first clearing action to evaluate clearing operations, and two back-to-back surveys following the second clearing action to evaluate the second clearing operation. It should be noted that two 70 kHz split-beam hydroacoustic transducers were used during the first two surveys, opposed to the 200 kHz transducers typically used, which theoretically should reduce interference from entrained air bubbles relative to the 200 kHz transducers. The data from the split-beam acoustics was unreliable using the 70 kHz transducers, potentially due to electrical interference at this particular frequency that was not detected at 200 kHz. Therefore, the last two surveys were conducted using our standard methodology employing the 200 kHz split-beam acoustic transducers. Further testing will be required with the 70 kHz transducers to determine their usefulness for future remote sensing surveys in the electric barrier system. Two fish targets > 12 inches were identified with side-scan SONAR during the first survey prior to clearing actions; results from split-beam acoustics were unreliable during this survey. Following the first clearing action, a single fish target > 12 inches was identified with side-scan SONAR during the second survey; results from split-beam acoustics were unreliable during this survey. During the third survey following the second clearing action, a single fish > 12 inches was detected with side-scan SONAR and was estimated to be ~15 inches. No fish > 12 inches were detected with split-beam acoustics during the third survey; interference from air bubbles and electricity was absent using the 200 kHz transducers. During the fourth and final survey, a single fish >12 inches was again detected with split-beam acoustics. It was estimated to be ~13 inches at a depth of 2.2 meters. In summary, there were between 1 and 2 fish >12 inches between Barriers 1 and Barrier 2 as of 14 November 2012 following barrier clearing actions.

Recommendations: The relationship between maximum side-aspect TS and TL used in these surveys (i.e., Love 1971) was developed from multiple species from several studies and includes fish that do or do not have gas bladders. It has been estimated that 50% of the dorsal- and side-aspect TS from a fish is generated by the gas bladder of fish (Jones and Pearce 1958), with the skeleton and flesh (Volberg 1963) and scales (Diercks and Goldsberry 1970) reflecting the other half, listed in decreasing order of magnitude. Thus, the dorsal- and side-aspect TS of a given fish species and size is an emergent property of the size and morphology of the gas bladder, body morphology, proximate composition, and possibly the type and size of scales. Given that the gas bladder of Asian carp are much larger than the majority of similar sized fish species in North America, the TS threshold used in these surveys was likely conservative for detecting Asian carp. Therefore information concerning the side-aspect TS for Asian carp would help to refine the search window for detecting Asian carp.

Target strength evaluations of Asian carp are ongoing at SIUC on-campus facilities in collaboration with the Illinois Natural History Survey and USFWS in which individuals are

tethered directly in front of the split-beam acoustic beam following sedation. The goal has been to quantify the side-aspect and dorsal aspect TS to body size relationship for Asian carp across a large size range as well as to determine the range of all acoustic properties specific to Asian carp such that single target detection algorithms can be optimized to detect Asian carp. To date, a total of 68 Silver Carp, 22 Bighead Carp, and 13 hybrid Asian carp have been evaluated to determine dorsal- and side-aspect target strength to body size relationships. All fish to date have been evaluated using the 200 kHz frequency, with a small proportion of them being evaluated with both the 70 and 200 kHz frequency after acquiring the new lower frequency. These data are currently being processed and analyzed.

A pilot study is being initiated in Spring 2013 in collaboration with the USFWS - Carterville Fish and Wildlife Conservation Office to increase the number of frequencies used to evaluate acoustic properties of Asian carp and other fishes to a total of four (i.e., 38, 70, 120, and 200 kHz). A Bayesian hierchical statistical approach will be used to define credibility intervals for estimates of body size as a function of acoustic TS for Asian carp. Multinomial logistic regression models will be used to determine whether probabilistic models can be developed to determine the likelihood that a given acoustically detected fish target can be classified as an Asian carp using a variety of acoustic properties. This model will include data from similarly bodied fishes, such as Common Carp and buffalo spp., and model selection procedures that will be used to narrow the list of candidate variables to key acoustic properties important for species classification. Although it is unknown whether multifrequency approaches will be successful at species classification, this pilot study will provide preliminary information regarding the utility of such an approach and whether further investigation is warranted.

Although 70 kHz split-beam hydroacoustic transducers were thought to reduce interference from entrained air bubbles due to the longer wavelength emitted relative to 200 kHz transducers, it was apparent that interference was greater using the 70 kHz frequency. The source of interference is unknown at this time and further testing is required to determine the appropriateness of using 70 kHz frequency transducers for remote sensing surveys at the electric barrier system. To determine if the source of interference is due to electrical interference, transects should be conducted in passive, listening mode following Mitson (1995) similar to those conducted with the 200 kHz transducers completed on 4 October 2011 that indicated no electrical interference in signal transmission from electric barrier system.

Project Highlights:

- The combination of split-beam hydroacoustics and side-scan SONAR has allowed for rapid assessment of the presence/absence of fish ≥ 12 inches TL over 97.6% of the entire water column within the electric barrier system and has provided real-time location information to facilitate targeted removal efforts.
- Confidence of detection probability using split-beam hydroacoustics and side-scan SONAR continues to increase as detections are confirmed by observations from the USFWS DIDSON camera as well as the capture of fish within the electric barrier system following detection.
- Recommend further refinement of the acoustic TS to body size relationship for Asian carp to determine uncertainty in size estimates.

- Recommend multi-frequency TS evaluations of Asian carp and other fishes to examine whether multinomial probabilistic models can be used to determine species-specific information.
- Recommend evaluation of 70 kHz frequency transducers for appropriateness of use in future surveys.

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Chapter 2:

Evaluating the efficacy of upstream harvest of Asian carp

David C. Glover, Marybeth K. Brey, and James E. Garvey; Southern Illinois University Carbondale

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 are part of an integrated control strategy for reducing the risk of Asian carp from gaining access to the Great Lakes. In 2011 alone, 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). Further, declines in catch per effort (CPE) are evident each year in most of these pools. In 2011, three separate hydroacoustic surveys, conducted by Southern Illinois University Carbondale (SIUC), 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 factors, such as emigration from the study area, could help explain Asian carp population dynamics in these upstream areas. This information is important for determining the efficacy of harvest in these upper reaches of the Illinois River and 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 in spring 2012 within the HMSC east and west pits to estimate population size, movement patterns, and exploitation rates for Asian carp. With assistance from IDNR contracted commercial fishermen, a total of 320 Asian carp (279 Bighead Carp, 34 Silver Carp, and 7 hybrids) were captured on 2 May and 3 May 2012 with gill nets. Fish were weighed (nearest g), TL measured (nearest mm), tagged with individually numbered $5 reward jaw tags (alumimum, size 1242-9C, National Band and Tag Co.), and released at the site of capture. Recoveries of tagged fish were recorded from contracted commercial fishermen throughout the Barrier Defense Asian Carp Removal Project. Fliers were provided to IDNR personnel, contracted commercial fishermen, and fish processing plants to increase awareness of the mark-recapture study and to provide reporting instructions. The reward amount was clearly marked on the jaw tag with contact information. Abundance of

Asian carp was also estimated using hydroacoustic surveys in the east and west gravel pits from 9/18/2012 to 9/20/2012 (see Chapter 4 concerning hydroacoustics for details).

Fixed-station 24-hour hydroacoustics surveys were conducted on 17 July, 17 September, and 15 November 2012 to examine the amount of fish movement in and out of the HMSC backwater. Either two 70 kHz or two 200 kHz split-beam transducers (BioSonics, Inc.) were mounted in the side-looking aspect and were positioned perpendicularly across the channel to track fish movements through the majority of the channel leading into this backwater (Figure 1). Transducers were mounted on dual axis rotators that allowed precise control over the angle that data were collected, and the pan and/or tilt was readjusted every 45 seconds if necessary. One transducer was set to maintain an angle perpendicular with the second transducer and offset downward to maximize the water column volume sampled.

Immigration and emigration rates, as well as movement between the east and west gravel pits of the HMSC backwater are also being estimated with acoustic telemetry. Specifically, with assistance from IDNR contracted commercial fishermen and Illinois Natural History Survey (INHS), 41 Asian carp were tagged with Vemco® acoustic transmitters (v16, v13, v9, or v6 transmitting at 69 KHz) within the east pit of HMSC, 164 fish were tagged in the Starved Rock Pool near Sheehan Island, 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. A total of 30 Vemco® VR2W receivers have been deployed in the Illinois River by SIUC to monitor movement of acoustically tagged Asian carp (Alton = 9, LaGrange = 7, Peoria = 6, Starved Rock = 4, and Marseilles = 4). These receivers have been placed around lock chambers 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 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 (see Chapter 5 for more details concerning acoustic telemetry). Additional Asian carp were tagged with acoustic transmitters by the U.S. Army Corps of Engineers (USACE) in the HMSC east pit (N = 18) and west pit (N = 13); the USACE also have additional telemetry receivers further upstream.

Results and Discussion: IDNR contracted commercial fishermen harvested a total of 19,456 Asian carp from the east pit of the HMSC over the course of the 2012 Barrier Defense Asian carp Removal Project. Of the 320 Asian carp externally tagged in the HMSC gravel pits, a total of 156 marked individuals were harvested (49%). Only 3 individuals were recaptured outside of this backwater in nearby areas (i.e., two from Peacock Slough and one from the main channel on the Marseilles reach). This suggests that emigration rates of Asian carp were very low, which increased their susceptibility to harvest. However, following acoustically telemetered fish indicated that movement in and out of this area is relatively high with 57% of fish tagged in the MSP moving out at some point in 2012. Combining these data suggests that Asian carp are residents in the backwater, but make short forays into the main channel.

Additional analyses of acoustically tagged fish indicated that emigration rates from the HMSC east pit out into the main channel were particularly high (up to 62%) during fishing periods (Figure 2). However, three of the highest observed emigration rates were from individuals that were just released after tagging. Discounting these potentially confounding observations, emigration rates were not affected by fishing (X_1^2 = 1.89; P = 0.17) with an overall emigration rate of 2.5% (95% CI = 1.5 to 3.3%). Additional data are currently being retrieved from telemetry receivers and will provide information for testing the potential effects of fishing disturbance on emigration rates without further confounding effects of immediate post-tagging movement. Further analyses will also be conducted to determine whether water level or temperature affects the net movement of Asian carp within this backwater.

Excluding the three Asian carp that were caught outside of the HMSC backwater and 15 that were recaptured during the USGS water gun experiments in this area, the estimated exploitation rate for this backwater area was 76% over a 20 week period for non-immigrants (i.e., the fish present at the beginning of the mark-recapture study). However, the proportion of marked individuals harvested declined at a faster rate than did CPE of Asian carp (Figures 3a and 3b), suggesting that immigration into this backwater increased at a faster rate than those removed through harvest. A Link-Barker mark-recapture model indicated that the rate of population change was positive from May through August due to high immigration, after which harvest was able to outpace the lower immigration rates (Figure 3c). It is important to note that recaptures from October through December 2012 only recently became available, thus analyses were conducted using only harvest records through September 2012. Further analyses will need to be conducted to determine the importance of late fall and winter harvest at decreasing local population abundances while Asian carp movement is minimal. This late-year harvest could be essential at keeping densities low prior to spring movement so that these backwaters can serve as a population sink rather than a source for upstream movement toward the CAWS.

Data collected with fixed-station hydroacoustics are currently being processed and data from telemetry receivers are currently 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. A spatially explicit model that incorporates movement among reaches is needed to fully understand these population dynamics and to determine how immigration and emigration affect these estimates. A modeling summit will be held in 2013 to discuss various modeling approaches to address harvest strategies that minimize the probability of Asian carp movement toward the CAWS.

Recommendations: Although overall return rate was exceptionally high for a mark-recapture study, estimates of exploitation and population rate of change had extremely high standard errors due to a small proportion of tagged individuals in the population, albeit without a complete data set available for analysis. An increase in the number of tagged individuals is warranted and simulations using the trends estimated from the 2012 mark-recapture study will be used to determine the number required to achieve more precise estimates. The trends in CPE suggest that tagging earlier in the year should increase the probability of tagging additional Asian carp. If increasing the number of tagged individuals at the beginning of the study cannot dampen

standard errors, as determined from our simulations, it may be necessary to tag throughout the fishing season. Therefore, various simulations will be conducted to determine the best approach for increasing precision of estimates.

We assumed that the tag reporting rate was 100%. Commercial fishermen have been diligent about reporting recapture information, yet specific information concerning the date and location of capture has been incomplete, particularly in the earlier portion of the study from May to July 2012. IDNR observers have exercised increased diligence on recording recaptures, to better relate estimates of movement between the east and west gravel pits to the timing of commercial fishing and environmental correlates (e.g., water level). Given that an increase in the number of tagged individuals appears necessary and recapture rates of these fish is extremely high, the reward structure may need to be reconsidered. Rather than providing a reward for every recaptured fish, a lottery system may be necessary in which certain tags are given varying levels of rewards.

We also assumed that tag loss was negligible for these analyses and could therefore have affected these results. Given that estimates of emigration appeared to be exceptionally high due to the declining proportions of marked individuals harvested, determining tag loss is needed. We recommend the use of an additional mark, either using a PIT tag, Carlin Dangler tags, or a non-invasive fin clip to keep mortality at a minimum.

Project Highlights:

- Of the 320 Asian carp externally tagged in the HMSC backwater near Morris, IL in May 2012 a total of 149 (~47%) marked individuals were harvested through IDNR contracted commercial fishing efforts by the end of September 2012.
- Emigration of Asian carp from the HMSC backwater was low, increasing susceptibility to harvest.
- The estimated exploitation rate for this backwater area was 76% over a 20 week period for non-immigrants (i.e., the fish present at the beginning of the mark-recapture study).
- Despite the high exploitation rates found in this study, estimates concerning the population rate of change suggest that harvest was unable to outpace immigration until August. This suggests that late fall and winter harvest may be important for decreasing local population abundances while Asian carp movement into the backwater is minimal.

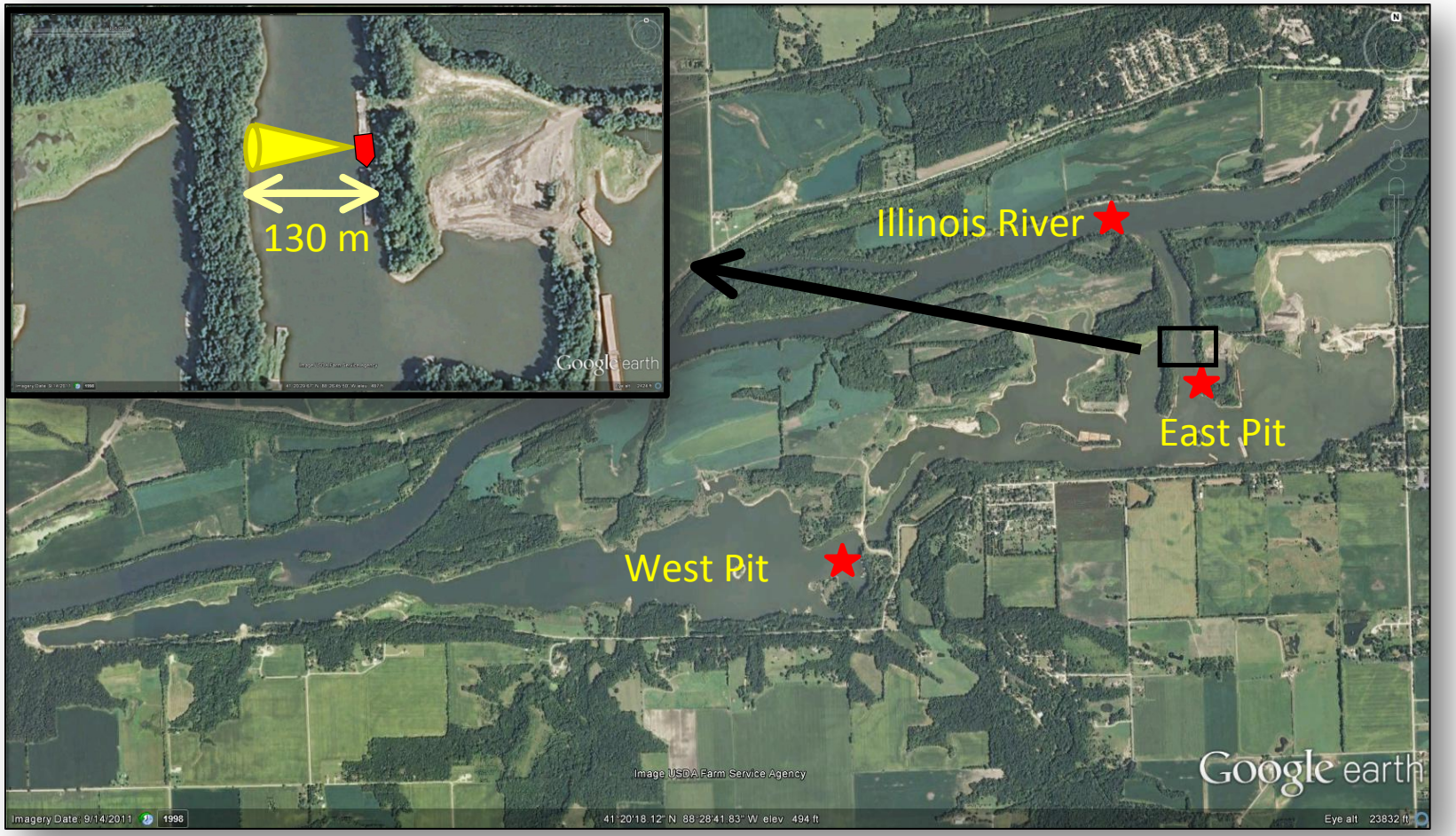

Figure 1. Map of Hanson Material Services Corporation backwater near Morris, IL indicating locations of VR2 receivers to quantify movement in/out of this backwater and between the west and east pits. The inset displays the location of 24-hr fixed acoustics across the ~130-m channel connecting the backwater to the main channel of the Illinois River.

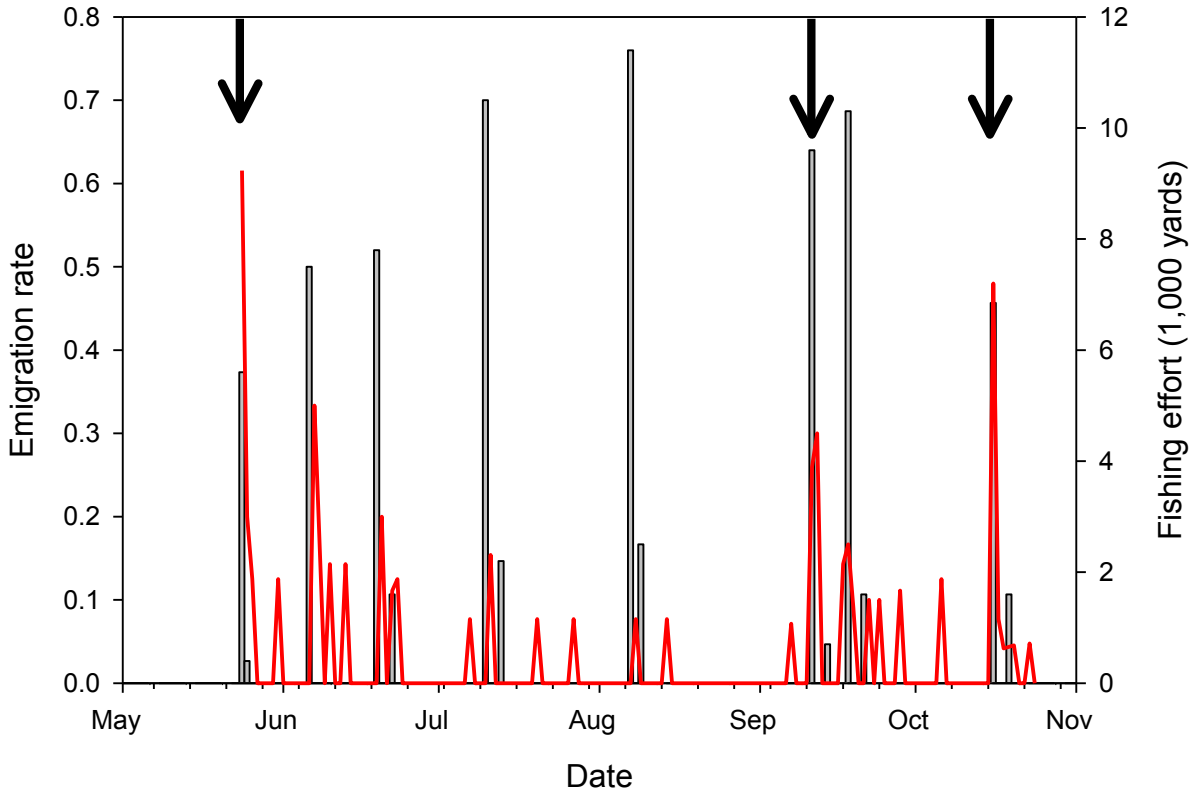

Figure 2. Emigration rate (solid red line) of acoustically tracked Asian carp correcting for net movement on the number of fish within Hanson Material Services Corp. east pit. The level of IDNR contracted commercial fishing effort (grey bars) is indicated by the right axis and only included data from the HMSC east pit. Timing of tagging is indicated by solid black arrows (the first two tagging event were conducted by SIUC and the last event was conducted by USACE).

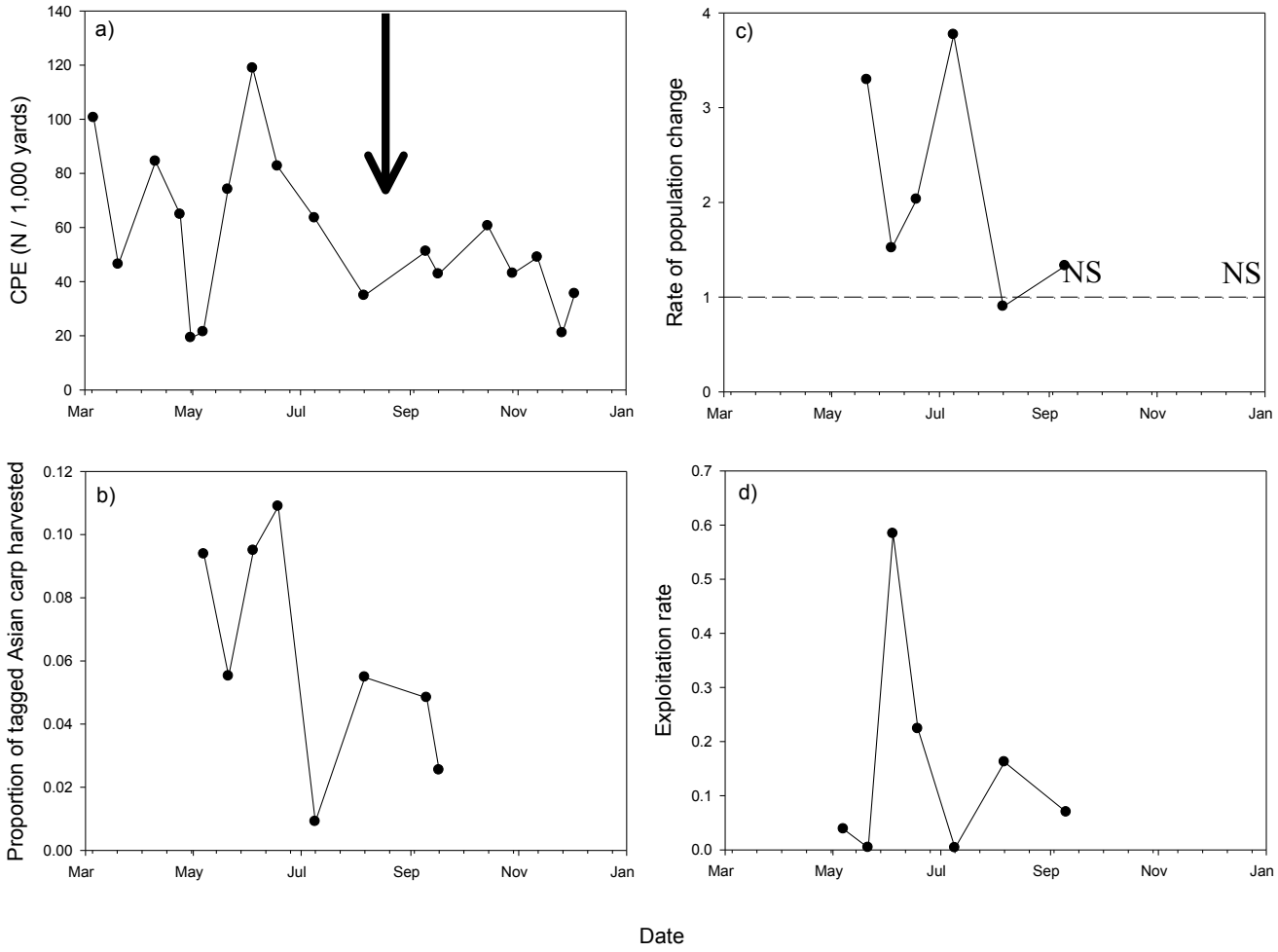

Figure 3. a) Catch per effort (CPE) of Asian carp from IDNR contracted commercial fishermen in 2012 with the time of tagging indicated by an arrow, b) proportion of tagged Asian carp recaptured correcting for those previously removed, c) rate of population change with values near one indicating no population change (NS indicates no significant change in the population), and d) exploitation rate plotted as a function of time.

Chapter 3:

Standardized sampling on the Illinois River

David C. Glover, Wesley Bouska, Marybeth K. Brey, and James E. Garvey; Southern Illinois University Carbondale

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

Introduction: Periodic standardized sampling of aquatic invasive species can provide useful information for tracking changes in the demographics of a population over time. These data provide a baseline from which to assess the impacts of commercial fishing and harvest of Asian carp in the Illinois River. Although Asian carp have been detected in the lower Illinois River 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 to better forecast population dynamics in the future to 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 6-11, 2012 (Table 1). Two pulsed-DC electrofishing transects (fifteen minutes each) 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 (Table 2; 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 technique 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

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. The trammel net effort expended often depended on the 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 for 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, in each reach only five Silver Carp individuals within 50-mm length group intervals had post cleithera removed and gonad weight taken for GSI. After this minimum sample size was achieved, silver carp were measured, weighed and sexed. All Bighead Carp were completely processed given that they are much rarer than Silver Carp. Otoliths were removed from all Bighead Carp and placed in microcentrifuge vials for otolith microchemistry.

To identify, quantify and determine maternal contribution of parental Bighead Carp, Silver Carp, and their hybrids, fin clips from a pectoral fin of 414 Asian carp were taken in the field from a subset carp collected in 2012 and placed in 75% ethanol. Samples were sent to Jim Lamer at Western Illinois University for processing. DNA extraction, genotyping, and data processing are currently underway using 60 SNP nuclear DNA assays for parental and hybrid assignment and

one mitochondrial SNP to determine maternal contribution to the hybrids. Genetic analysis will be conducted on an additional 400 Asian carp in 2013.

Data Analysis:

Catch per unit effort
Electrofishing catch per unit effort (CPUE; number of fish per hour) was calculated for Silver and Bighead Carp. Changes in CPUE from 2011 to 2012 were compared for each species for the whole river, and by each reach using a paired t-test in which each sampling location was treated as a unit of replication.

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 the entire sample using an age-length key. Silver Carp mean length-at-age was compared among reaches and years using a two-way Analysis of Variance (ANOVA). Comparisons were made for age classes 2.5 to 6.5; younger and older age classes 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. Too few data were available for Bighead Carp to conduct a two-way ANOVA on mean length-at-age.

Mortality
Catch-curve analysis was used to determine annual mortality rates for Silver Carp. Fish ≤ age 2.5 appeared to be under-represented in our sampling efforts, likely because they had not fully recruited to the sampling gear, and were therefore omitted from the analysis. Analysis of Covariance (ANCOVA) was used to determine whether mortality rates (i.e., slopes) were different among reaches as well as between 2011 and 2012. 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, Bighead Carp, and Gizzard Shad 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 between 2011 and 2012, using an ANCOVA. Too few data permitted a proper analysis of length-weight relationships among other species.

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. Too few data points were available to test Bighead Carp size at maturity.

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 will be genetic identities, allele frequencies, and maternal contribution of 400 Asian carp per year for two years from the Illinois River from the CAWS down to the confluence with the Mississippi River.

Results and Discussion:

Fish collection
Combined electrofishing and trammel net effort at 19 sites resulted in the collection of 2,571 fishes, including 36 different species (Table 3). 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
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 2011 to 102.1 fish/hour (SE = 22.8) in 2012 ($P = 0.0027$; Figure 1). 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. We have collected fish movement data in the Illinois River using telemetry that may answer this question.

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 of 2012 for conversion to fish meal 45% was composed of Bighead Carp according to subsamples taken at the fish processor. 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 for fish meal and other purposes may provide a better indication of whether declines in Bighead Carp abundance are occurring.

It is also important to note that the youngest Asian carp year class captured in either 2011 or 2012 was the 2010 year class, albeit with a lower sampling efficiency for these sized fish.

Mean length-at-age

In 2011, mean length-at-age for Silver Carp differed among reaches for age classes 2.5 and 3.5, where fish from the La Grange reach had a significantly larger mean TL ($P < 0.0002$), and there were no differences in mean length-at-age among reaches for the other age classes tested ($P > 0.09$; Figure 2). In 2012, mean length-at-age for Silver Carp differed among most reaches across most age classes. Comparisons among reaches and years showed that in the Alton reach, mean length-at-age was significantly reduced from 2011 to 2012 ($P < 0.05$) for all ages except 3.5, which showed no change. Mean length-at-age increased for age 3.5 in the La Grange reach from 2011 to 2012 ($P < 0.0001$). In the Peoria reach, mean length-at-age increased for age 2.5 and decreased for age 5.5 from 2011 to 2012 ($P \leq 0.037$).

Differences in Silver Carp mean length-at-age among reaches was much more variable in 2012 than in 2011. In 2011 age 2.5 and 3.5 Silver Carp were significantly longer in the La Grange reach compared to other reaches. This trend followed these cohorts into 2012, with age 3.5 and 4.5 Silver Carp being significantly longer in the La Grange reach than Alton or Peoria. Other observed changes in mean length-at-age in 2012 were less intuitive. The Alton reach showed significantly lower mean lengths-at-age compared to 2011 for all age classes except 3.5. Coupled with a significantly reduced CPUE in the Alton reach from 2011, this could be evidence of commercial fishing impacts. In the Peoria reach we caught more age 5.5 fish in 2012, but they were significantly shorter than those caught in 2011. Finally, where we saw no differences in mean length-at-age among reaches for age classes 4.5 onward in 2011, in 2012 Silver Carp age 5.5 were significantly longer in the La Grange reach and age 6.5 Silver Carp were significantly longer in the Peoria reach. These differences 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 reaches, emigration or immigration among reaches or river systems. The necessary data to make any strong conclusions about these observed changes in size-at-age are currently not available.

Mortality

Annual mortality rates for Silver Carp collected in all reaches combined was estimated to be 0.675 (95% CI = 0.528 – 0.776; Figure 4) 2012. No differences in annual mortality were evident between Alton ($A = 0.463$) and La Grange ($A = 0.593$), or between La Grange and Peoria ($A = 0.75$; $P > 0.14$). Annual mortality rates between the Alton and Peoria reaches were significantly different ($P = 0.014$). Estimated mortality was counter-intuitively higher in Peoria than Alton

despite the suggestion that harvest effects were stronger in Alton based on the relative change in CPUE between these reaches. This anomaly was likely the effect of a dominant 2008 year class in the Alton reach. Specifically, this year class had a strong carryover into 2012 and resulted in a reduced number of age 3.5 fish compared to age 4.5 fish and subsequently flattened the slope of the catch curve, producing an artificially low annual mortality rate for the Alton reach. Fish movement between the reaches could also explain this phenomenon. Movement data will be further analyzed to provide a better estimate of mortality in these reaches.

Despite increased harvest, estimated annual mortality rates in 2012 did not differ from 2011 for all reaches combined ($P = 0.888$) or between reaches ($P > 0.235$). Further analyses are needed to determine whether certain ages, particularly older fish, have been significantly reduced. Piece-wise regression techniques would be more appropriate than linear catch-curve approaches (Maceina 2007). For example, in the 2011 and 2012 sampling events, the 2008 year class dominated our sample in all three reaches and remained the dominant year class in Alton in 2012. However, there appeared to be a reduction in this year class in the Peoria and La Grange reaches as the 2007 year class became dominant in our 2012 collections in these reaches. Given that Silver Carp growth rates are generally slower in Alton compared to La Grange and Peoria, 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. Alternatively, immigration of from the Mississippi River could contribute to the higher proportion of 2008 individuals in the lower reaches.

Length-weight relationships

Analysis of covariance indicated that the intercept and slope of the length-weight relationships were significantly different among reaches for Silver Carp collected in 2012 (slope: $P < 0.0001$; intercept: $P < 0.0001$), but only the intercept was different among reaches for Bighead Carp (slope: $P = 0.074$; intercept: $P = 0.02$; Table 4). Specifically, Silver Carp length-weight relationship parameters were different among all reaches ($P < 0.05$). In general, Silver Carp collected from Alton tended to be heavier at smaller sizes and skinnier at larger sizes relative to other reaches. Silver Carp tended to be the skinniest from La Grange at small sizes, but were heavier at larger sizes compared to the other two reaches. For Bighead Carp, the intercept was significantly higher for the Alton reach compared to La Grange and Peoria reaches ($P < 0.03$), but was similar between La Grange and Peoria (Table 4). Increased sample sizes of Bighead Carp would be needed to make conclusions regarding reach-specific changes in condition.

Few changes were found in length-weight relationships between 2011 and 2012 for Asian carp. The slope of this relationship for Silver Carp did not differ between years for the Alton ($P = 0.89$) and Peoria reaches ($P = 0.31$), but increased from 3.032 in 2011 to 3.226 in 2012 ($P < 0.001$). Similarly, no differences were detected in the intercept between years for Alton and Peoria, yet declined from -5.092 in 2011 to -5.622 in 2012. The change in intercept was more of an anomaly from the correlation between slope and intercept, as increases in size-specific mass were most evident at larger sizes. Low sample sizes of Bighead Carp in the Alton and La Grange reaches captured in 2012 precluded comparisons between years, and no differences were found in the slope ($P = 0.143$) or intercept ($P = 0.533$) parameters for Bighead Carp in Peoria between 2011 and 2012.

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 541-mm TL for the La Grange reach ($P = 0.031$), and 506-mm TL for the Peoria reach ($P = 0.0006$) and was indicative of the size at maturity (Figure 5). Based on our age-length key, these estimates correspond to an age-at-maturity between age 3 and 4. For the Alton reach, variation in GSI was statistically homogenous across TL ($P = 0.269$) potentially due to small sample size (N = 15). Mean GSI for female Silver Carp ranged from 0.013 (SE = 0.0043) to 0.064 (SE = 0.017) among reaches (Table 5). Mean GSI for female Bighead Carp ranged from 0.0017 (SE = 0.0028) to 0.0064 among reaches (Table 5). 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 of Silver Carp collected in 2012 were significantly different from 1:1 for all reaches combined ($P = 0.009$) with males becoming more dominant by 17%. This is in contrast to data collected from 2011 that indicated the sex ratio was not different from 1:1. Differences from a 1:1 sex ratio were not detected at the reach level ($P = 0.344$), however, likely due to lower sample sizes when reaches were treated separately. It will be important to continue monitoring this in the future to make inferences about the potential intrinsic rate of increase of Asian carp abundance.

Molecular identification of Asian carp
Genotyping of Asian carp individuals is still underway and will be completed by April 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 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 commercial fishing on Asian carp continues to increase. Although we appear to be seeing immediate demographic responses due to size-selective harvest of Asian carp, we remain cautiously optimistic. These demographics need to be monitored continually to determine whether factors such as increased growth rates, condition, and reproductive success 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 information concerning species-specific proportion of abundance and changes in length-weight relationships among fishes is imperative information to determine abundance and biomass of Asian carp and other fishes 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 2012 relative to 2011 for Silver Carp in the three lower reaches of the Illinois River.
- Relative to 2011, electrofishing catch per unit effort (CPUE) was significantly reduced by 33% for all three lower reaches combined in 2012. In the Alton reach, 2012 CPUE was reduced by more than half relative to 2011.
- In comparison to 2011, length-at-age was significantly smaller in 2012 in the Alton reach for all age classes except for age-3 Silver Carp, likely due to size selective harvest of larger individuals.
- Asian carp sex ratios in the combined lower three reaches of the Illinois River appear to be gradually shifting from the equal sex ratio in 2011 to a more male dominated population in 2012 with approximately 17% more males than females, possibly due to size selective harvest of larger females.
- No age-1 or YOY Asian carp were collected in the three lower reaches of the Illinois River in 2012, indicating that 2011 and 2012 were poor recruitment years.

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Table 1. Standardized sampling locations and effort for the three lower reaches of the Illinois River, 2012. 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 Code	Location name	Habitat type	Electrofishing (min)	Trammel Nets (m)	Latitude	Longitude
Alton						
A-MC1	Grafton	Main channel	30	-	38°58'14.19"N	90°27'42.26"W
A-MC2	Hardin	Main channel	30	-	39° 9'23.29"N	90°36'47.83"W
A-BW2	Side channel Mortland Island	Side channel	30	548.64	39°7'39.04"N	90°36'48.17"W
A-MC3	Florence	Main channel	30	-	39°37'42.20"N	90°36'26.60"W
A-BW3	Side channel Big Blue Island	Side channel	30	548.64	39°39'34.14"N	90°37'21.09"W
A-MC4	Meredosia	Main channel	30	-	39°49'55.62"N	90°33'58.36"W
A-BW4	Meredosia Lake	Backwater lake	-	-	39°52'57.27"N	90°32'44.18"W
LaGrange						
L-MC1	MC near Lilly Lake	Main channel	31.5	-	39°58'42.00"N	90°30'44.12"W
L-BW1	Lilly Lake	Backwater lake	30	548.64	39°59'16.39"N	90°30'29.33"W
L-MC2	Frederick	Main channel	30	-	40° 7'29.25"N	90°22'3.85"W
L-BW2	Wood slough	Backwater lake	13	274.32	40° 4'52.82"N	90°22'46.42"W
L-MC3	Havana	Main channel	30	-	40°20'12.76"N	90° 2'57.76"W
L-BW3	Quiver Lake	Backwater lake	30	548.64	40°20'10.72"N	90° 2'45.20"W
L-MC4	Peoria Lock and Dam	Main channel	30	-	40°37'21.76"N	89°38'12.47"W
Peoria						
P-MC1	Upper Peoria Lake	Main channel	31	-	40°47'34.08"N	89°33'43.45"W
P-MC2	Chillicothe	Main channel	29	-	40°55'3.85"N	89°28'42.78"W
P-BW2	Sawmill Lake	Backwater lake	30	-	41° 7'14.69"N	89°19'30.50"W
P-MC3	Henry	Main channel	30	-	41° 6'18.07"N	89°21'26.53"W
P-BW3	Senachwine Lake	Backwater lake	25	548.64	41° 9'35.61"N	89°20'12.00"W
P-MC4	Hennepin	Main channel	30	-	41°15'30.63"N	89°20'54.70"W

Table 2. LTRMP standardized electrofishing power settings (in watts or peak volts*amps) for various water conductivities and temperatures. Electrofishing at these power settings ensures potential transfer of 3,000 watts from water to fish (Burkhardt and Gutreuter 1995).

Conduc-tivity	Temperature °C									Conduc-tivity	Temperature °C								
	5	10	15	20	35	30	35	40	45		5	10	15	20	35	30	35	40	45
25	8859	7896	7164	6588	6125	5745	5427	5159	4929	275	3012	3054	3118	3196	3284	3380	3481	3587	3696
35	6809	6130	5615	5212	4889	4626	4407	4224	4068	285	3019	3070	3141	3225	3320	3421	3529	3640	3755
45	5684	5164	4772	4467	4225	4029	3867	3733	3620	295	3029	3087	3165	3256	3356	3464	3577	3694	3814
55	4980	4563	4251	4010	3820	3668	3545	3444	3360	305	3039	3105	3190	3287	3394	3507	3626	3749	3874
65	4501	4158	3902	3707	3556	3436	3340	3263	3202	315	3051	3124	3216	3319	3432	3551	3676	3804	3935
75	4159	3870	3658	3498	3375	3280	3206	3148	3104	325	3064	3145	3243	3353	3471	3596	3726	3860	3996
85	3904	3658	3480	3348	3249	3174	3117	3076	3045	335	3079	3166	3270	3386	3511	3642	3777	3916	4058
95	3710	3499	3348	3239	3159	3101	3060	3032	3013	345	3094	3188	3299	3421	3551	3687	3828	3973	4120
105	3558	3376	3249	3159	3096	3053	3025	3008	3001	355	3110	3211	3328	3456	3592	3734	3880	4030	4182
115	3438	3281	3174	3102	3053	3023	3006	3000	3003	365	3127	3234	3357	3491	3633	3781	3932	4087	4245
125	3343	3207	3118	3060	3025	3006	3000	3004	3015	375	3144	3258	3388	3528	3675	3828	3985	4145	4308
135	3266	3150	3076	3032	3008	3000	3004	3016	3036	385	3162	3283	3419	3564	3717	3876	4038	4204	4372
145	3203	3105	3046	3014	3001	3002	3015	3036	3063	395	3181	3308	3450	3601	3760	3924	4091	4262	4436
155	3153	3070	3024	3003	3001	3012	3032	3061	3096	405	3201	3334	3482	3639	3803	3972	4145	4321	4500
165	3113	3044	3010	3000	3007	3026	3055	3091	3134	415	3221	3360	3514	3677	3846	4021	4199	4380	4564

Table 2, continued.

Conduc-tivity	Temperature °C								
	5	10	15	20	35	30	35	40	45
175	3081	3025	3003	3002	3018	3045	3082	3125	3174
185	3056	3012	3000	3009	3033	3068	3112	3163	3218
195	3036	3004	3002	3020	3052	3095	3146	3203	3265
205	3021	3000	3008	3034	3074	3124	3182	3245	3314
215	3011	3000	3016	3051	3098	3155	3220	3290	3364
225	3004	3003	3028	3070	3125	3189	3260	3336	3417
235	3001	3009	3042	3092	3154	3224	3301	3384	3470
245	3000	3018	3059	3116	3184	3261	3345	3433	3525
255	3002	3028	3077	3141	3216	3299	3389	3483	3581
265	3006	3040	3097	3168	3250	3339	3435	3535	3638

Conduc-tivity	Temperature °C								
	5	10	15	20	35	30	35	40	45
425	3242	3387	3546	3715	3890	4070	4253	4440	4628
435	3263	3414	3579	3753	3934	4119	4308	4499	4693
445	3284	3442	3613	3792	3978	4168	4362	4559	4758
455	3306	3470	3646	3831	4022	4218	4417	4619	4823
465	3328	3498	3680	3870	4067	4268	4472	4679	4888
475	3351	3527	3714	3910	4112	4318	4527	4740	4954
485	3374	3555	3749	3950	4157	4368	4583	4800	5019
495	3397	3584	3783	3990	4202	4419	4639	4861	5085
505	3421	3614	3818	4030	4248	4469	4694	4922	5151
515	3445	3643	3853	4071	4293	4520	4750	4983	5217

Table 3. Common name, scientific name, species code, and total number of fish collected for each species by reach from the Illinois River in 2012.

Common name	Scientific name	Code	Alton	La Grange	Peoria
Bighead carp	*Hypopthalmichthys nobilis*	BHCP	2	4	15
Bullhead minnow	*Pimephales vigilax*	BHMW	0	4	3
Black buffalo	*Ictiobus niger*	BKBF	12	14	6
Black crappie	*Pomoxis nigromaculatus*	BKCP	1	2	1
Bluegill	*Lepomis macrochirus*	BLGL	7	5	4
Bigmouth buffalo	*Ictiobus cyprinellus*	BMBF	3	25	4
Bowfin	*Amia calva*	BWFN	0	7	0
Common carp	*Cyprinus carpio*	CARP	31	32	26
Channel catfish	*Ictalurus punctatus*	CNCF	5	15	5
Emerald shiner	*Notropis atherinoides*	ERSN	6	29	25
Flathead catfish	*Pylodictis olivaris*	FHCF	11	6	6
Freshwater drum	*Aplodinotus grunniens*	FWDM	17	38	34
Goldeye	*Hiodon alosoides*	GDEY	2	1	0
Goldfish	*Carassius auratus*	GDFH	1	0	0
Green sunfish	*Lepomis cyanellus*	GNSF	4	1	0
Grass carp	*Ctenopharyngodon idella*	GSCP	6	15	8
Gizzard shad	*Dorosoma cepedianum*	GZSD	177	268	225
Highfin carpsucker	*Carpiodes velifer*	HFCS	0	1	1
Largemouth bass	*Micropterus salmoides*	LMBS	1	2	7
Longnose gar	*Lepisosteus osseus*	LNGR	7	23	2
Quillback	*Carpiodes cyprinus*	QLBK	0	0	2
River carpsucker	*Carpiodes carpio*	RVCS	33	1	12
River redhorse	*Moxostoma carinatum*	RVRH	1	2	0
Sauger	*Stizostedion canadense*	SGER	1	1	3
Shorthead redhorse	*Moxostoma macrolepidotum*	SHRH	0	1	0
Skipjack herring	*Alosa chrysochloris*	SJHR	6	2	10
Smallmouth buffalo	*Ictiobus bubalus*	SMBF	12	39	112
Smallmouth bass	*Micropterus dolomieu*	SMBS	0	0	2
Shortnose gar	*Lepisosteus platostomus*	SNGR	14	26	3
Spotted bass	*Micropterus punctulatus*	STBS	1	0	0
Spotted gar	*Lepisosteus oculatus*	STGR	0	2	0
Spottail shiner	*Notropis hudsonius*	STSN	0	0	3
Silver carp	*Hypopthalmichthys molitrix*	SVCP	146	417	532
Unidentified minnow	Unidentified Cyprinidae	U-CY	0	2	0
Warmouth	*Lepomis gulosus*	WRMH	0	1	0
White bass	*Morone chrysops*	WTBS	3	16	8
Total species			26	31	26
Unique Species			2	4	2
Total fish sampled			510	1002	1059

Table 4. Parameter values from the length-weight relationships ($\log_{10}$mass = a' + b · $\log_{10}$TL) for Silver Carp and Bighead Carp collected from the lower three reaches of the Illinois River in 2012. Parameter estimates with different letters indicate significantly different values between reaches ($P < 0.05$) as determined by ANCOVA.

Reach	a'	SE	b	SE	R^2	P	N
			Silver carp				
Alton	-4.807[a]	0.187	2.926[a]	0.069	0.93	<0.0001	144
La Grange	-5.622[c]	0.098	3.226[c]	0.036	0.95	<0.0001	417
Peoria	-5.302[b]	0.068	3.110[b]	0.025	0.97	<0.0001	530
			Bighead carp				
Alton	-4.593[a]	0.402	2.876[a]	0.141	0.97	<0.0001	2
La Grange	-4.659[b]	0.401	2.876[a]	0.141	0.97	<0.0001	4
Peoria	-4.641[b]	0.392	2.876[a]	0.141	0.97	<0.0001	15

Table 5. Mean gonadosomatic index (GSI) for Bighead Carp and Silver Carp by reach and sex in the Illinois River, 2012.

Species	Sex	N	Mean GSI	SE
		Alton		
Bighead Carp	F	1	0.0064	0
Bighead Carp	M	1	0.0016	0
Silver Carp	F	15	0.013	0.0043
Silver Carp	M	24	0.0009	0.0002
		La Grange		
Bighead Carp	F	0	-	-
Bighead Carp	M	4	0.00125	0.00052
Silver Carp	F	23	0.06	0.0074
Silver Carp	M	23	0.0019	0.00045
		Peoria		
Bighead Carp	F	7	0.0017	0.00028
Bighead Carp	M	7	0.00065	0.00023
Silver Carp	F	23	0.064	0.0168
Silver Carp	M	25	0.0016	0.00042

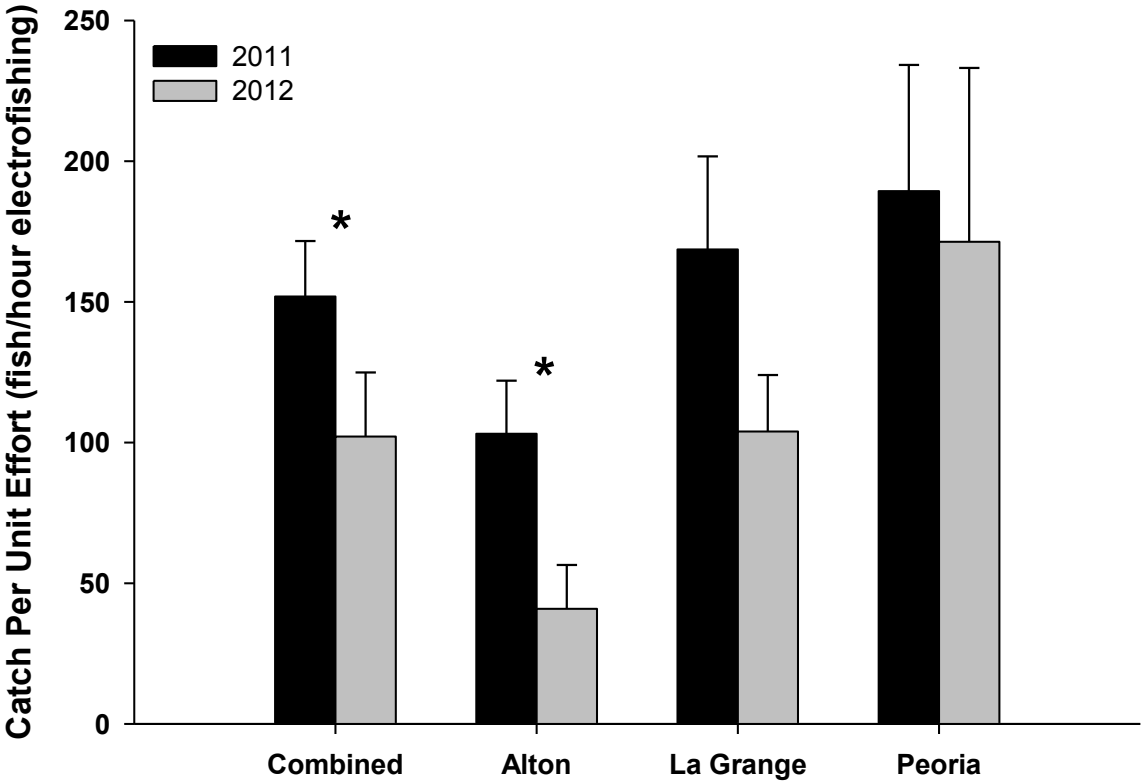

Figure 1. Electrofishing catch per unit effort from standardized fish sampling conducted in 2011 and 2012 for the lower three reaches of the Illinois River combined and for each reach; asterisk indicates a significant difference in CPUE among years ($P \leq 0.05$).

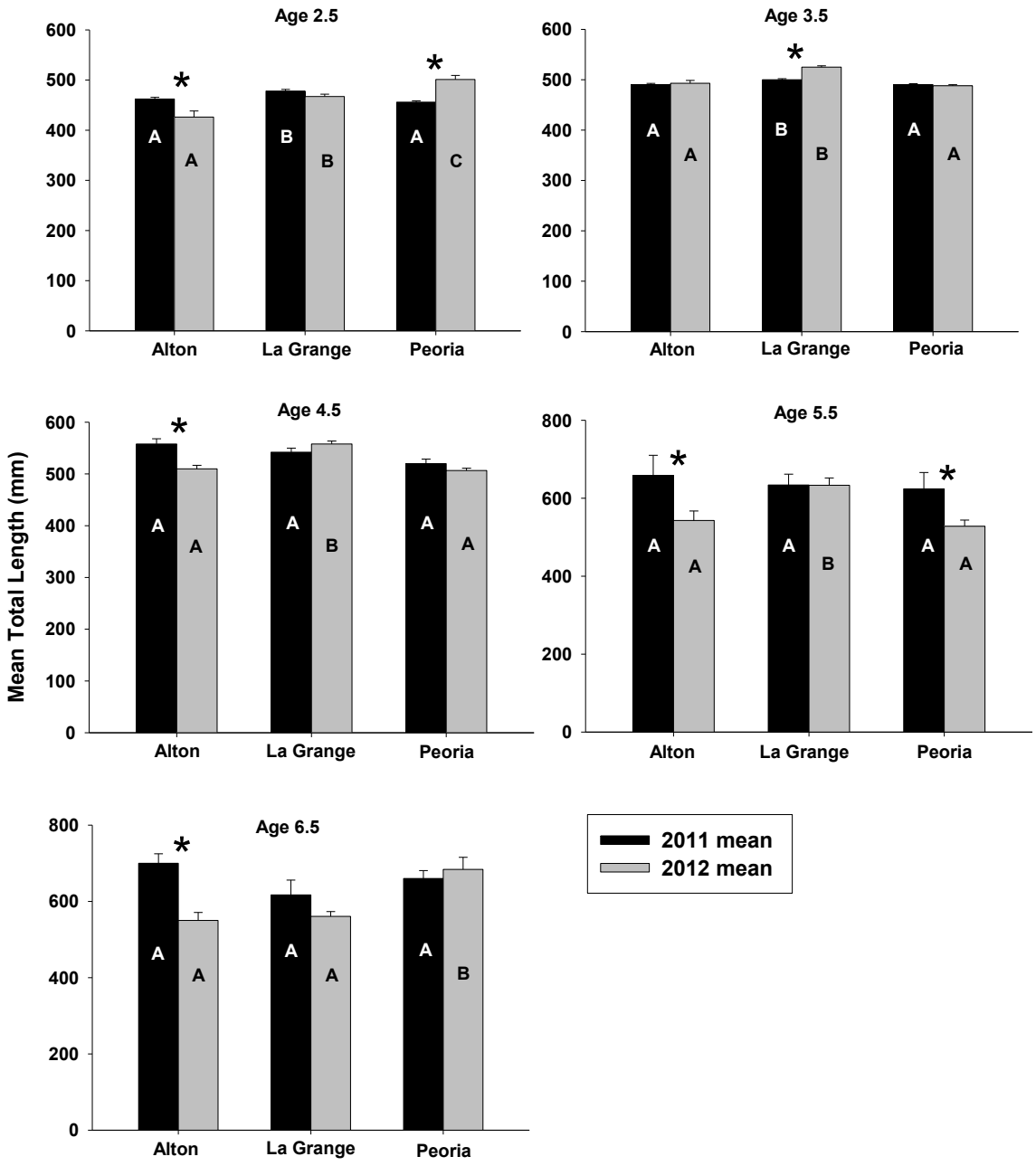

Figure 2. Mean length-at-age with associated standard error for Silver Carp in the three lower reaches of the Illinois River collected in 2011 and 2012; asterisks denotes a significant difference in mean total length among years, different letters indicate significantly different mean total lengths among reaches within 2011 or 2012 ($P \leq 0.05$), as determined by a two-way ANOVA.

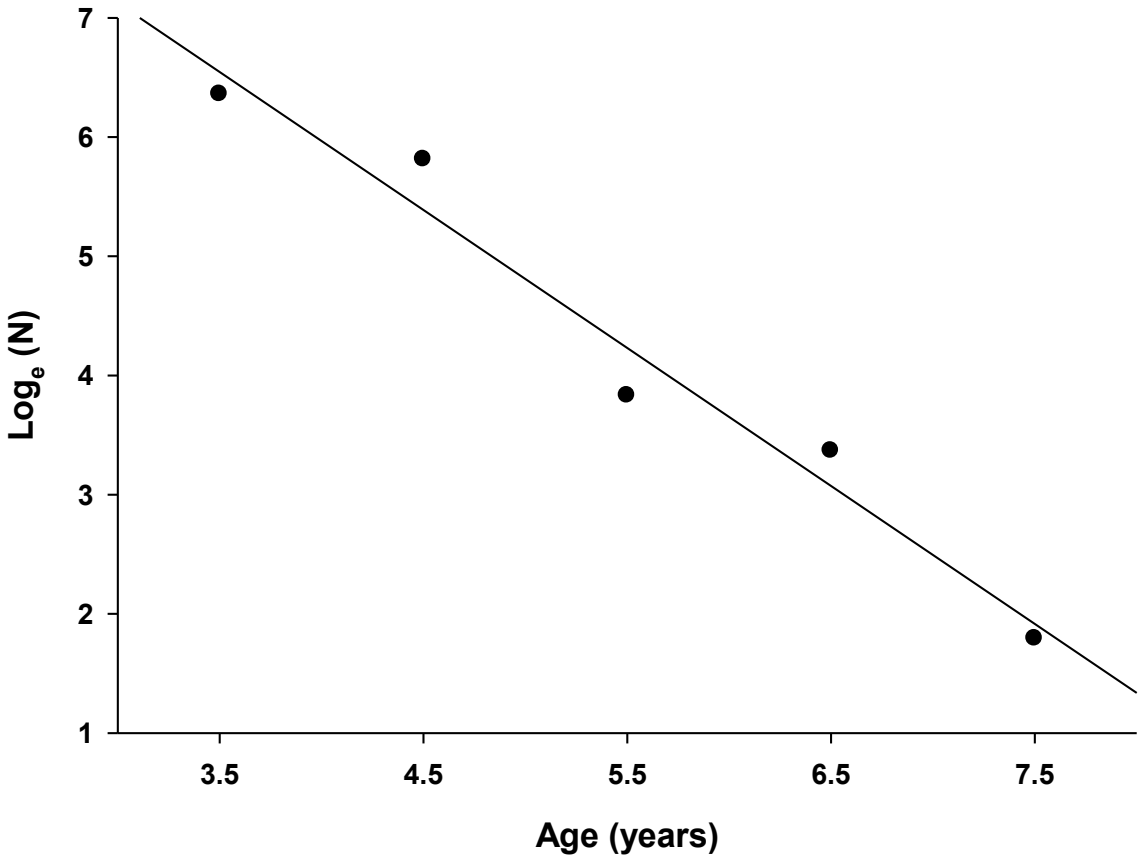

Figure 3. Natural-log transformed number of Silver Carp plotted as a function of age for the three lower reaches of the Illinois River and all sampling gears combined, 2012.

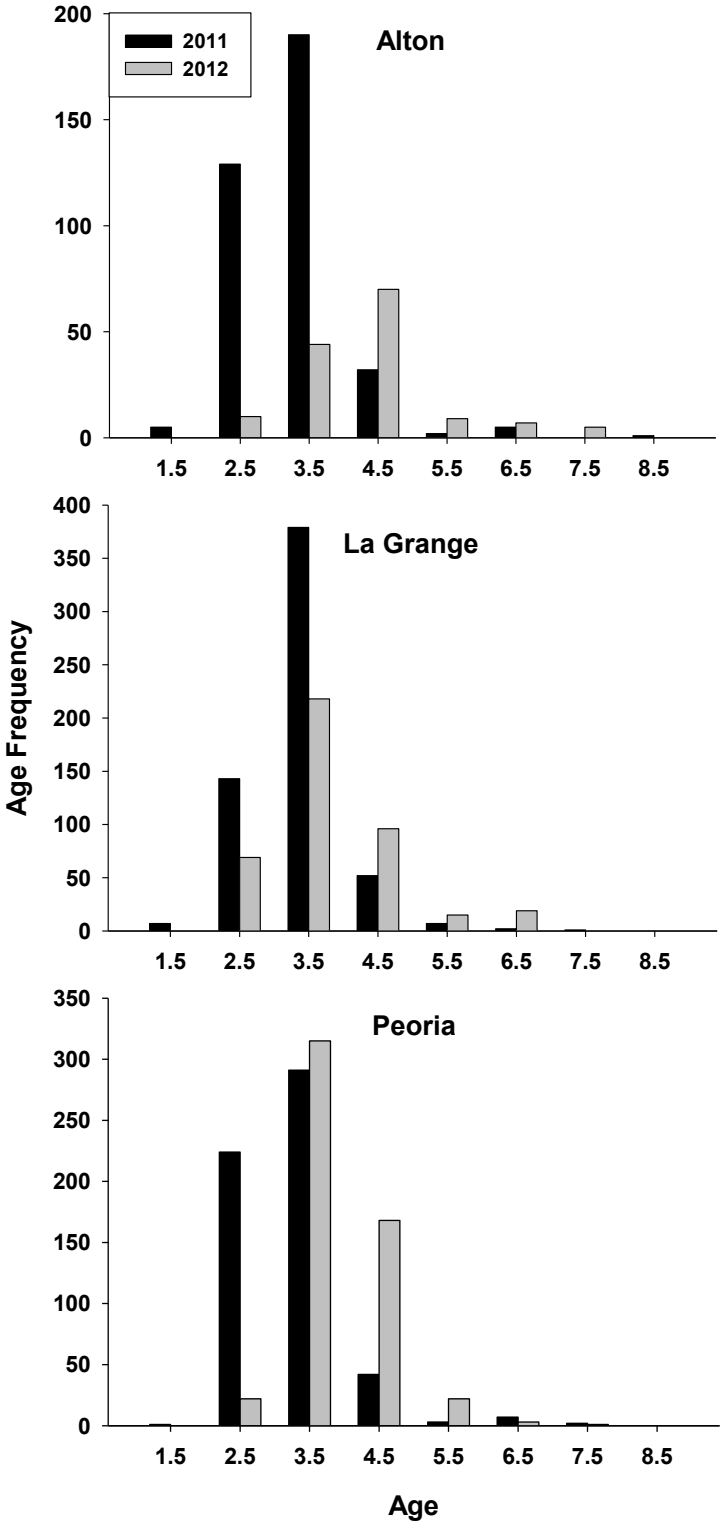

Figure 4. Age frequency for Silver Carp by reach for 2011 and 2012 collected in the Illinois River using pulsed-DC electrofishing and trammel netting.

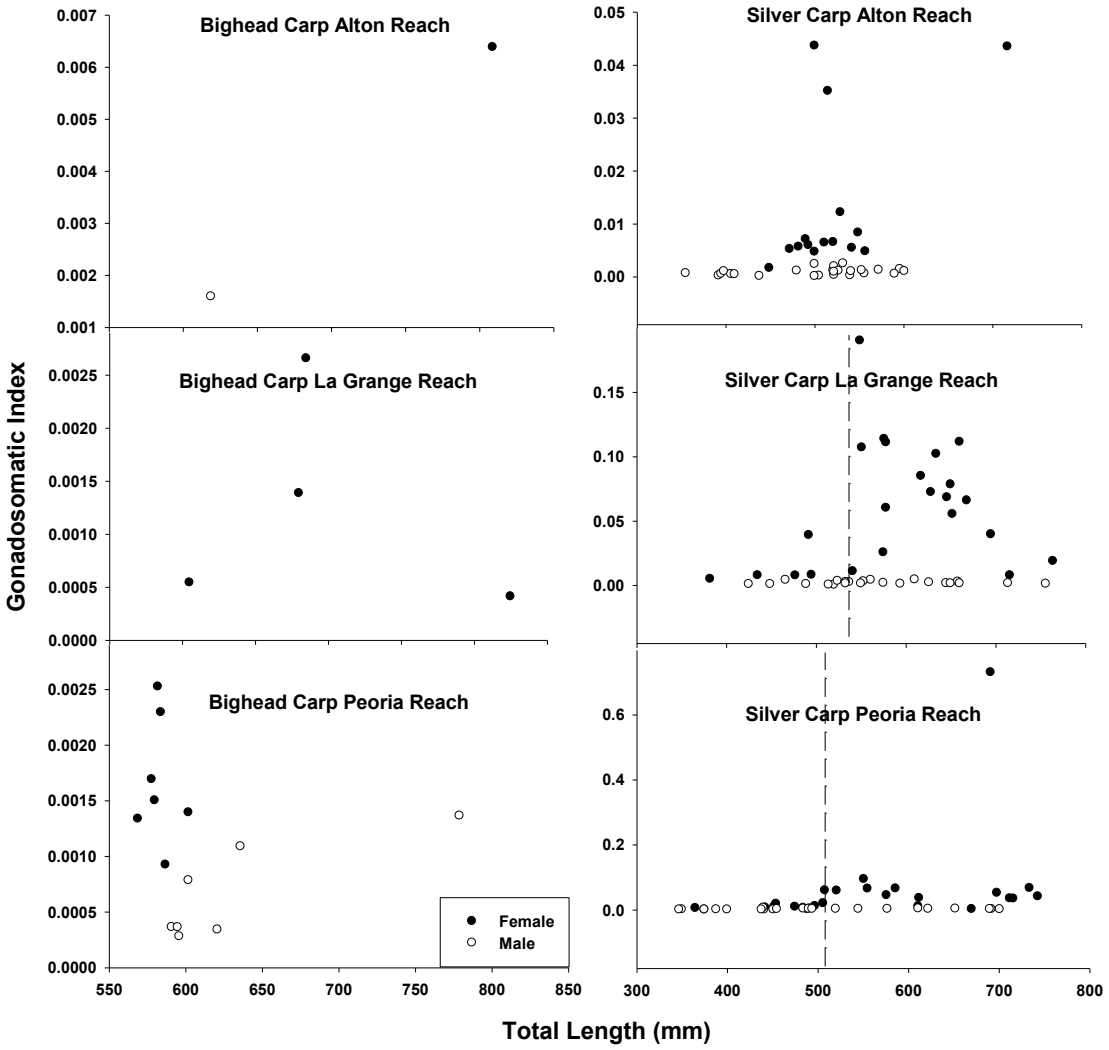

Figure 5. Gonadosomatic index of Bighead Carp and Silver Carp plotted by total length for each sex for the three lower reaches of the Illinois River, 2012. The dashed vertical line shows the total length at which variation in GSI increases for female Silver Carp as determined by a two-dimensional Kolmogorov Smirnov test ($P \leq 0.031$ for La Grange and Peoria reaches), GSI was statistically homogenous across TL in the Alton reach. Note the varying magnitude of scale for GSI among graph panels.

Chapter 4:

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

David C. Glover and James E. Garvey; Southern Illinois University at Carbondale

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 reaches) 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 acoustic techniques used in the 2010-2011 acoustic surveys did not allow for the surface waters (i.e., upper 1.15 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 (i.e., 3,422.5 river km of transect distance), 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 boarders 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 the incorporation of side-looking hydroacoustic techniques.

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 a combination of down-looking and side-looking hydroacoustics surveys 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 hydroacoustic estimates of reach-specific abundance, biomass, and size distribution of Bighead Carp and Silver Carp between down-looking and side-looking techniques to quantify the amount of Asian carp potentially missed near the surface and through potential evasion using down-looking techniques;
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 increased harvest.

Methods and Materials:

General overview
In the fall of 2012, a combination of hydroacoustic surveys and standardized sampling (i.e., pulsed-DC electrofishing and trammel netting) was 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 determine the total number and size distribution of all fishes within each reach. Data from standardized sampling will then be used to devise length-specific proportion 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.

Hydroacoustic sampling
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 4-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. Specifically, 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. 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.

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. Briefly, we used a stratified random sampling design to compensate for the spatial distribution of Asian carp. The 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 (Figure 1). Two side-looking 70 kHz split-beam transducers, located on the starboard side, were used simultaneously with the single port-side down-looking 200 kHz transducer. The 70 kHz transducers were mounted on dual axis rotators that allowed precise control over the angle at which data was collected, and 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. 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. 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 (Figure 2).

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 survey. Specifically, the dual axis rotators and 70 kHz 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 to travel on the left side of the channel when traveling upstream and on the right side of the channel when traveling 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, which blocked 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 used for the main channel. Fewer transects were typically needed to provide complete coverage due to the reduced width of these habitats. 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 200 kHz transducer and two side-looking 70 kHz transducers. 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. Additional transects were conducted using both 200 kHz transducers to fill in any spatial gaps, primarily to provide bathymetric information for volumetric estimates, particularly when depth was not uniform.

Acoustic data was 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).

Data Analysis:

Total fish abundance and size distribution

All acoustic data will be analyzed using EchoView 5.0 (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.

Species-specific abundance, size distribution, and biomass

Data collected from standardized sampling conducted in each reach during summer 2012 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. 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.

Given that the 2012 acoustic 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 from 2012 acoustic surveys to 2010-2011 estimates. 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 surveys.

Results and Discussion: During 2012, SIUC conducted hydroacoustic surveys 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).

These acoustics data are currently being processed 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. Moreover, 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 5.0 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 5.0 can produce these estimates, 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.

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 that may facilitate detections of these fish in areas without a form of directed sampling (Figure 4). Side-looking hydroacoustics could therefore be used to facilitate targeted removal of Asian carp where they exist in low number. In fact, hydroacoustic surveys conducted within the Starved Rock reach facilitated the identification of two sites for the Barrier Defense Asian carp Removal Project this fall, which was the mouth of the Fox River and Heritage Harbor where close to 50,000 lbs of Asian carp were subsequently removed between 18 October 2012 and 29 November 2012.

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. While some of

these backwaters do have sufficient depths for hydroacoustic sampling, the entrances into 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, as was seen in Hanson Material Service Corp. east pit, 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.

Although surveys were also conducted on Starved Rock and Marseilles along the main channel in 2010-2011, standardized sampling was not conducted in these reaches to inform acoustic estimates of the size-specific proportions of species composition. Therefore, we need to determine whether sufficient data exist from other agencies (e.g., IDNR, INHS) to estimate Asian carp abundance, biomass, and size-distributions within these reaches for comparison purposes to 2012 acoustic surveys.

Project Highlights:

- Collected over 2,300 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.
- The incorporation of side-looking hydroacoustic methods used in the fall 2012 surveys 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.
- Assisted with the location of dense schools of Asian carp for targeted harvest for the Barrier Defense Asian carp Removal Project.

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Table 1. Locations sampled with hydroacoustics within each reach, 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 dam 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**	

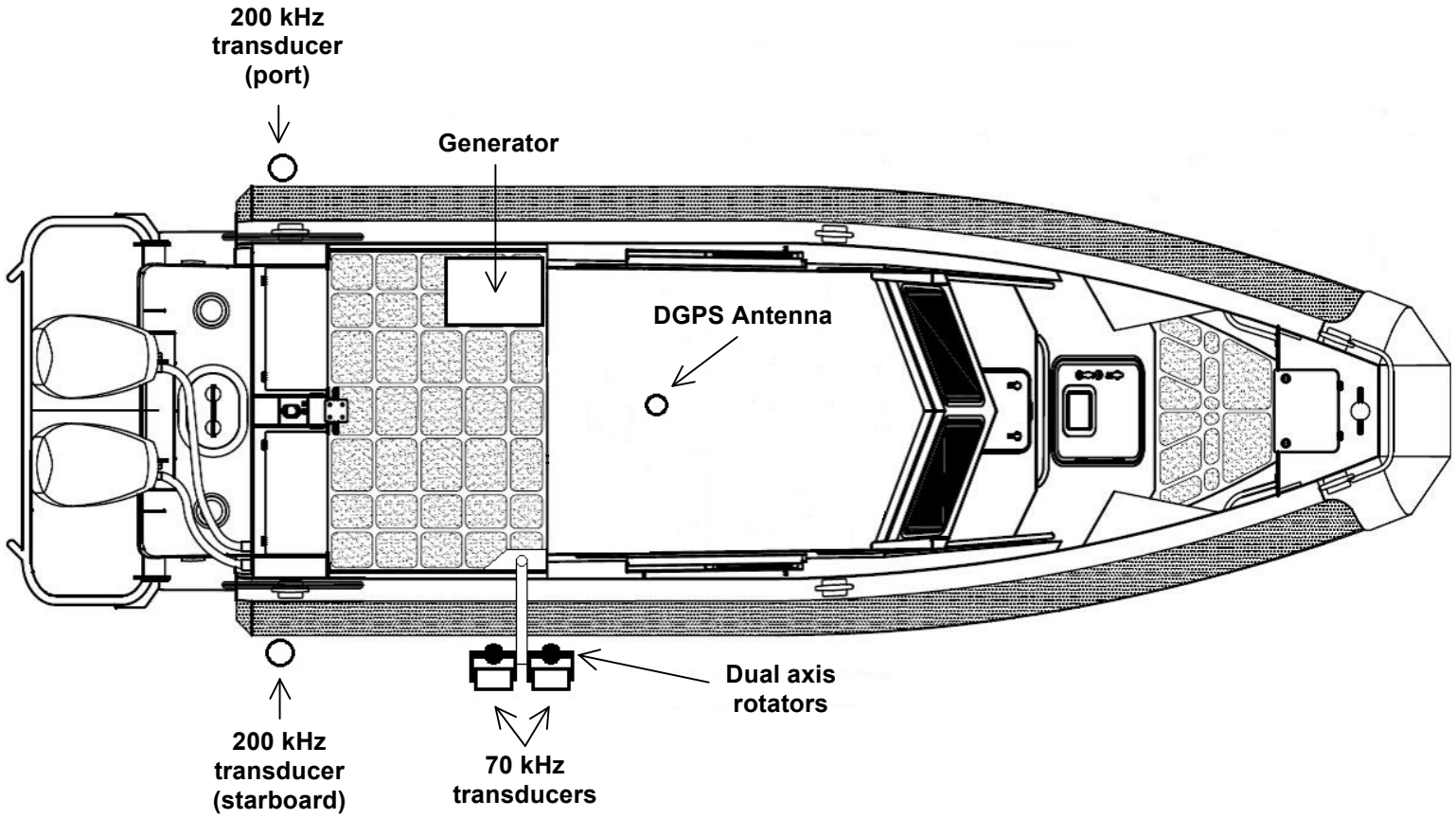

Figure 1. Schematic of the Shovelnose R/V indicating placement of dual axis rotators, split-beam hydroacoustics transducers, DGPS antenna, and generator.

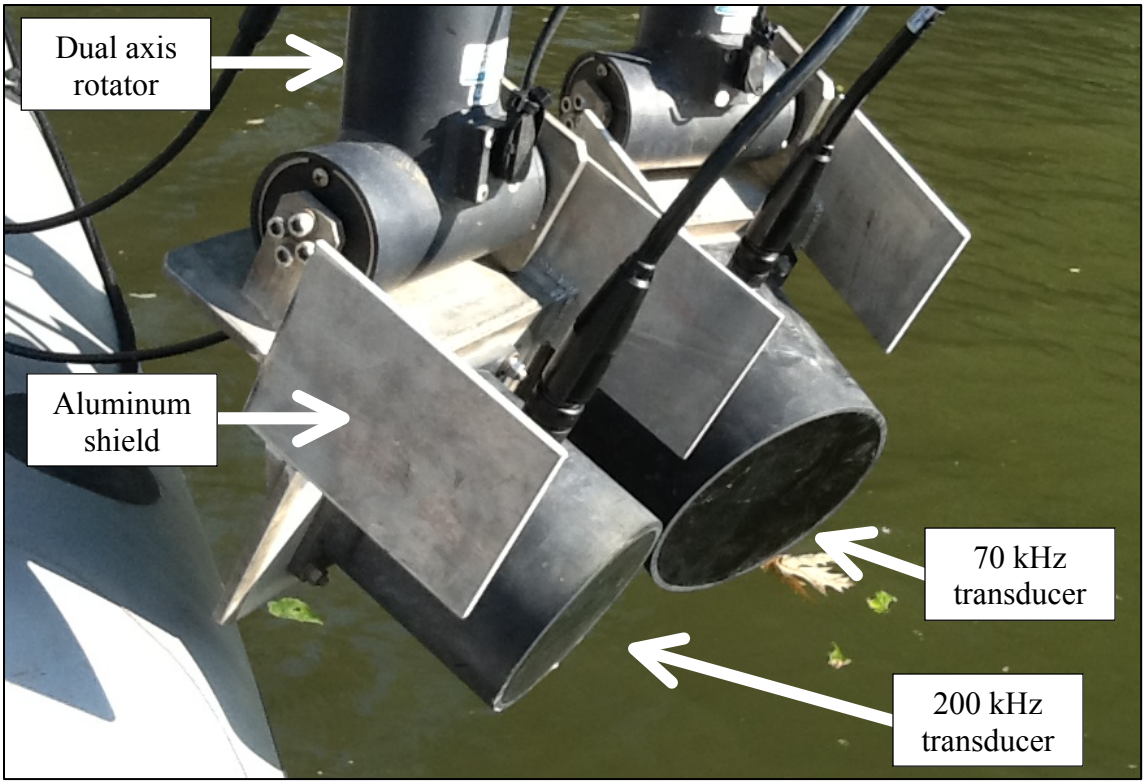

Figure 2. Photograph of split-beam hydroacoustics transducers mounted on dual axis rotators prior to deployment. The 200 kHz transducer (left) was used temporarily for side-looking transects while the second 70 kHz transducer (right) was repaired after breaking off the cable connection during a transect in Hanson Material Service Corp. east pit. The aluminum shielding was subsequently welded on to protect the plug from snagging on obstructions.

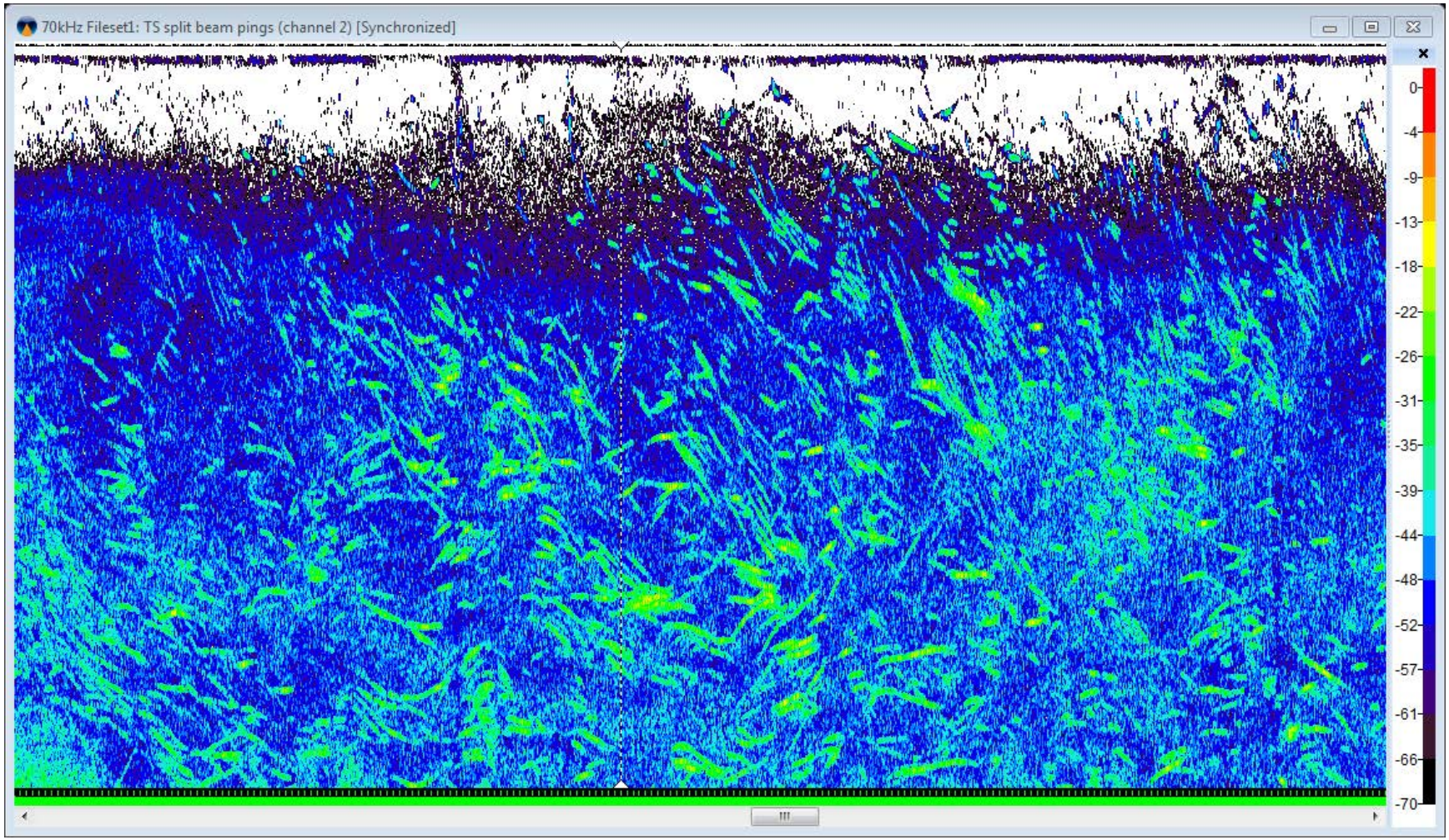

Figure 3. Echogram created in EchoView 5.0 from data collected using a 70 kHz side-looking split-beam hydroacoustic transducer in the side channel of the Alton reach behind Diamond Island (Dark Chute). The amplitude of the echoes is indicated on the right (dB) and represents uncompensated target strength. Similar to other areas with lower density, these fish tracks are often accompanied by jumping Silver Carp that land in the boat for proper species identification (D. Glover, personal observation). It is currently unknown whether Bighead Carp display the same erratic behavior or whether any of these targets are from Bighead Carp.

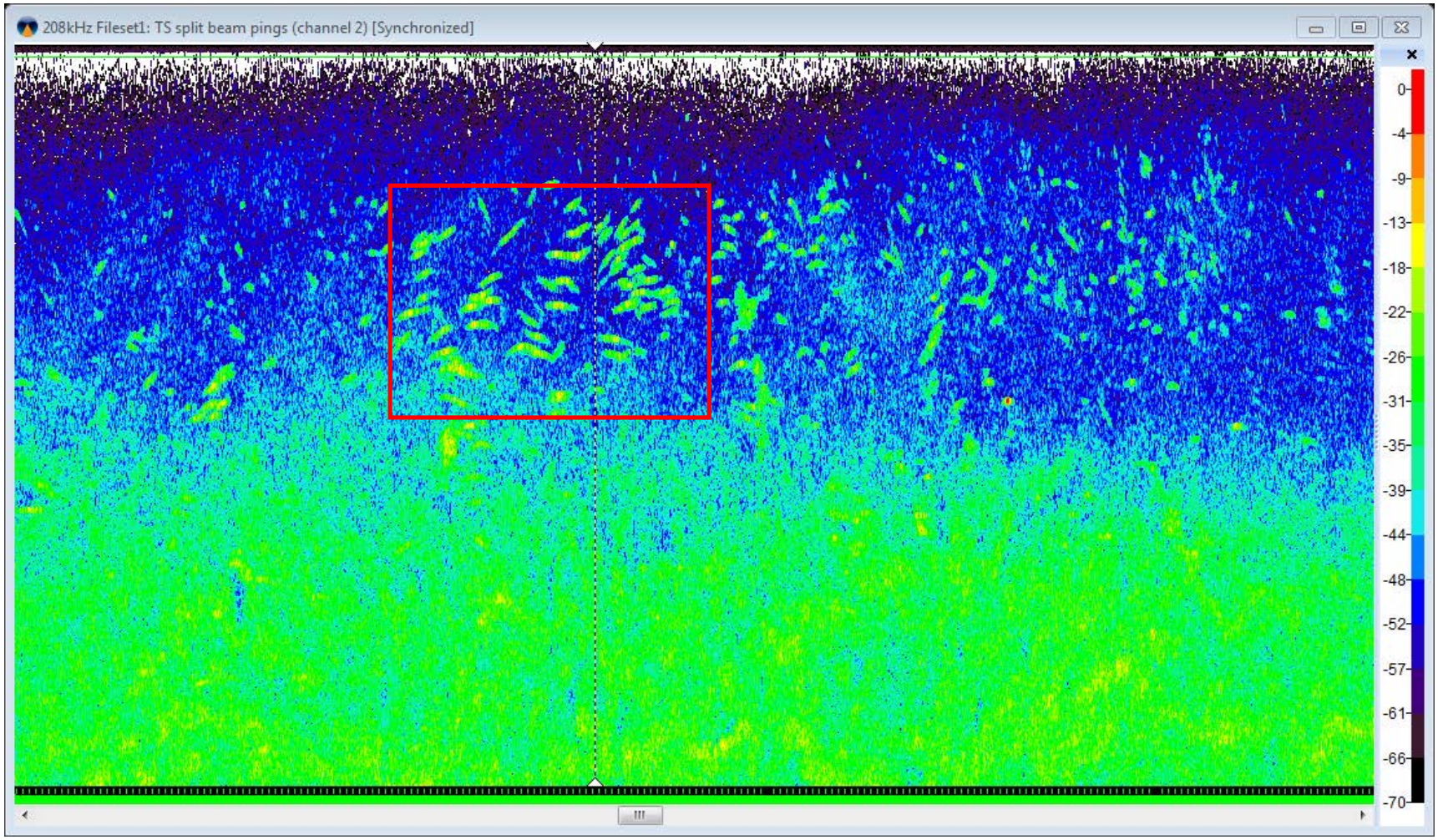

Figure 4. Echogram created in EchoView 5.0 from data collected on 23 September 2012 using a 200 kHz side-looking split-beam hydroacoustic transducer in the Kankakee River, approximately 0.5 RM from the Dresden Reach (41° 22.986′ N, 88° 15.888′ W). The amplitude of the echos are indicated on the right (dB) and represent uncompensated target strength. The fish targets in the red box displayed behavior similar to Silver Carp (see Figure 3).

Chapter 5:

Asian Carp Movement in the Illinois River

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

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

Introduction: Immigration and upstream movement of Asian carp were quantified with telemetry in 2010-2011, and indicated that 30% of Asian carp 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 (Garvey et al. 2012). Immigration and upstream movement corresponded with elevated flow in the river during spring through summer. 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 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 toward the Chicago Area Waterway System (CAWS). Periods of mass movement might be times when removal efforts need to be concentrated on the fish. If removal efforts are successful, then frequency of movement of fish toward the CAWS should decline through time. 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; 65 Bighead Carp, 9 Silver Carp, and 3 hybrid Asian carp). One hundred and sixty-four fish were tagged in the Starved Rock Pool near Sheehan Island, 41 were tagged in Marseilles Pool 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). 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 30 Vemco® VR2W receivers have been deployed in the Illinois River to monitor movement of acoustically tagged Asian carp (Alton = 9, LaGrange = 7, Peoria = 6, Starved Rock = 4, and Marseilles = 4; Table 2). These receivers have been placed around lock chambers and near major tributaries to track large-scale movements within and among reaches, though three receivers were placed within Hanson's Material Services Corp. gravel pits to better understand the factors affecting Asian carp immigration and emigration within this area. Three receivers were damaged or lost during 2012 and are currently being replaced. In addition, in 2013, VR2 Receivers will be placed in all lock and dam chambers including Dresden (already inserted), Marseilles, Starved Rock, Peoria, and La Grange as well as four additional side-channel or back water areas for a total of 37 active VR2W receivers on the Illinois River by February 2013. 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. Thirty-seven fish were relocated during this time period (Figure 2).

Discharge and temperature
Discharge measurements were collected using an ADCP (acoustic Doppler current profiler) at from the Mississippi River just below the Illinois River confluence, in the Illinois River just above the confluence, and in the Illinois River near Starved Rock during the weeks of June 18th and July 9th, 2012. Temperature loggers were also placed on all VR2W receivers to determine how movement relates to water temperature. Movement and temperature data have been and will continue to be downloaded at 2-month intervals to determine how discharge and water temperature affect movement of Asian carp.

Results and Discussion: To date, 17 of the fish tagged with acoustic transmitters have been captured. Specifically, seven of the fish tagged in the east pit of Hanson's Material Services Corp. and 10 tagged near Sheehan Island in the Starved Rock Pool have been recaptured by IDNR contracted commercial fishermen, four were unable to be released alive (3 Bighead Carp, 1 hybrid). In addition, two Bighead Carp tagged near Starved Rock were harvested by bow fishermen, and two Silver Carp tagged in Pool 26 were harvested by an independent commercial fisherman leaving a total of 72 tagged Asian carp still in the river.

Over 250,000 fish detections were recorded on passive VR2W receivers from 1 January to 23 October 2012 on VR2W receivers located along the Illinois River from Alton to Dresden Lock and Dam. From these detections, 157 individual Asian carp were identified out of 265 potentially at large during 2012 (including fish tagged in 2010 with active transmitters).

Only five fish (all Bighead Carp) were detected moving downstream through lock and dams. Two moved from the Marseilles reach (3.4%) to the Starved Rock reach and three from the Starved Rock reach to other downstream reaches (3.4% of those tagged). No upstream movement through lock and dams of fish tagged (by SIU) was detected in 2012 in the Starved Rock, Marseilles or Dresden Pools (Table 2). Fish tagged in the Starved Rock Pool showed extremely high site fidelity, with 40% of the fish tagged relocating within that pool. Nearly 20% (36 individual fish) of the fish tagged in the Sheehan Island backwater were relocated there up to seven months post-tagging, suggesting that Starved Rock Pool may act as a staging area for Asian carp and possibly a natural barrier to upstream movement.

Movement within the Marseilles Pool was also high with substantial movement occurring into and out of the Materials Services Pits (MSP). Fifty-seven percent of fish tagged in the MSP moved out at some point in 2012. Of the 13 Asian carp tagged by SIU in the Dresden Pool, three were relocated within the pool (23%) and one exhibited downstream movement (detected in the Materials Services Pits of the Marseilles reach).

Due to the low number of individual fish detections per pool and the lack of ADCP (flow) and temperature data available thus far for 2012 (May-October), analysis of any correlations between flow, water temperature, and fish movement is ongoing. Downloading of VR2W data for Oct-Dec 2012 is currently being completed and will be analyzed following retrieval. Results will be distributed as they become available.

Recommendations: Due to the enormous amount of data collected in 2012 and the ongoing nature of the project, completing analysis is not possible because data collection and summarization are ongoing. We will continue to monitor Asian carp movement though the Illinois River in 2013. 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. Because we believe lock and dams to be a potential barrier to upstream movement of Asian carp, we are currently placing VR2Ws in all lock chambers along the Illinois River and recommend continued monitoring of these areas in 2013. In addition, we documented the heavy use of the Material Services Pits in the Marseilles reach by Asian carp. To better identify how

much immigration exists to this area we recommend tagging more fish with acoustic transmitters within the Marseilles Pool not located within the MSP.

Highlights:

- In 2012, 372 Asian carp were tagged with Vemco® acoustic transmitters in the Illinois River (Marseilles, Starved Rock, and Dresden Pools) and in Pool 26 of the Mississippi River (124 Bighead Carp, 243 Silver Carp, and nine hybrid Asian carp).
- 30 VR2W receivers located along the Illinois River from Alton to Dresden Lock and Dam picked up over 250,000 fish detections from 1 January to 23 October 2012. From these detections, 157 individual Asian carp were identified.
- No upstream movement of any tagged carp from Starved Rock, Marseilles, or Dresden was detected during 2012.
- Fish tagged in the Starved Rock Pool showed extremely high site fidelity, with 40% of the fish tagged relocated within that pool.
- While no fish were detected moving upstream past Marseilles Lock and Dam, three Bighead Carp (3.4%) moved downstream through the Starved Rock Lock and Dam into the Peoria or LaGrange Pools.
- Movement within the Marseilles Pool was high with substantial movement occurring into and out of the Materials Services Pits.
- Of the 13 Asian carp tagged by SIU in the Dresden Pool, three were relocated within the pool (23%) and one exhibited downstream movement (detected in the Materials Services Pits of the Marseilles reach).

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Table 1. Number, total length (TL; mm) and weight (g) of Bighead, Silver and hybrid Asian carp tagged in the Illinois River in 2012.

Pool Released	Species	Number tagged	Mean TL (g; ±SD)	Length (TL) Range	Mean weight (g; ±SD)	Weight range (g)
Pool 26	Bighead	19	557 ± 52	436-632	1,986 ± 489	890-2,700
	Hybrid	5	623 ± 57	569-714	2,392 ± 526	2,030-3,310
	Silver	131	615 ± 80	354-852	2,684 ± 1,086	510-8,150
Starved Rock	Bighead	58	798 ± 72	536-970	5,181 ± 1,371	1,030-8,900
	Silver	106	724 ± 79	471-865	5,094 ±1,818	890-8,900
Dresden	Bighead	8	929 ± 196	740-1359	7,996 ± 2,749	4,610-11,600
	Silver	5	801 ± 15	783-821	5,578 ± 331	5,250-6,050
Marseilles	Bighead	35	916 ± 104	719-1,115	8,130 ± 4,284	1,028-17,910
	Hybrid	4	756 ± 117	645-904	5,595 ± 3,152	2,670-9,350
	Silver	1	935	935	8,810	8,810
	All	372	712 ± 134	354-1359	4,434 ± 2,619	510-17,910

Table 2. The probabilities of movement (number detected post-tagging divided by the total number at large for a given reach) of Asian carp from the tagging reach (Starved Rock, Marseilles, Dresden and Pool 26) to the re-detected location (movement location).

Tagging origin	Movement location:	Proportion moved	Number detected post-tagging	Number at large
Starved Rock:				163
	Downstream	0.018	3	
	Starved Rock (within)	0.399	94[a]	
	Upstream	0.000	0	
Marseilles Pits:				58
	Downstream	0.034	2	
	Within the Marseilles Pool	0.569	33	
	Out of Pits (stayed out)	0.466	27	
	Out of Pits, then back in (once)	0.034	2	
	Continuously in and out of Pits	0.069	4	
Dresden to:				30
	Marseilles Pool	0.033	1	
	Within the Dresden Pool	0.067	2[b]	
Pool 26 to:				309[c]
	Alton	0.045	14	
	LaGrange	0.019	6	
	Alton to LaGrange to Alton	0.010	3	
	Alton to La Grange to Peoria to Alton	0.003	1	
	Aton to LaGrange to Peoria to LaGrange	0.006	2	
	Upstream then back downstream	0.019	6	

[a] Includes 29 fish detected by VR100 active tracking not detected by VR2Ws

[b] Relocated in Dresden Pool by USACE using VR100.

[c] Includes carp tagged in 2010 that still have active transmitters.

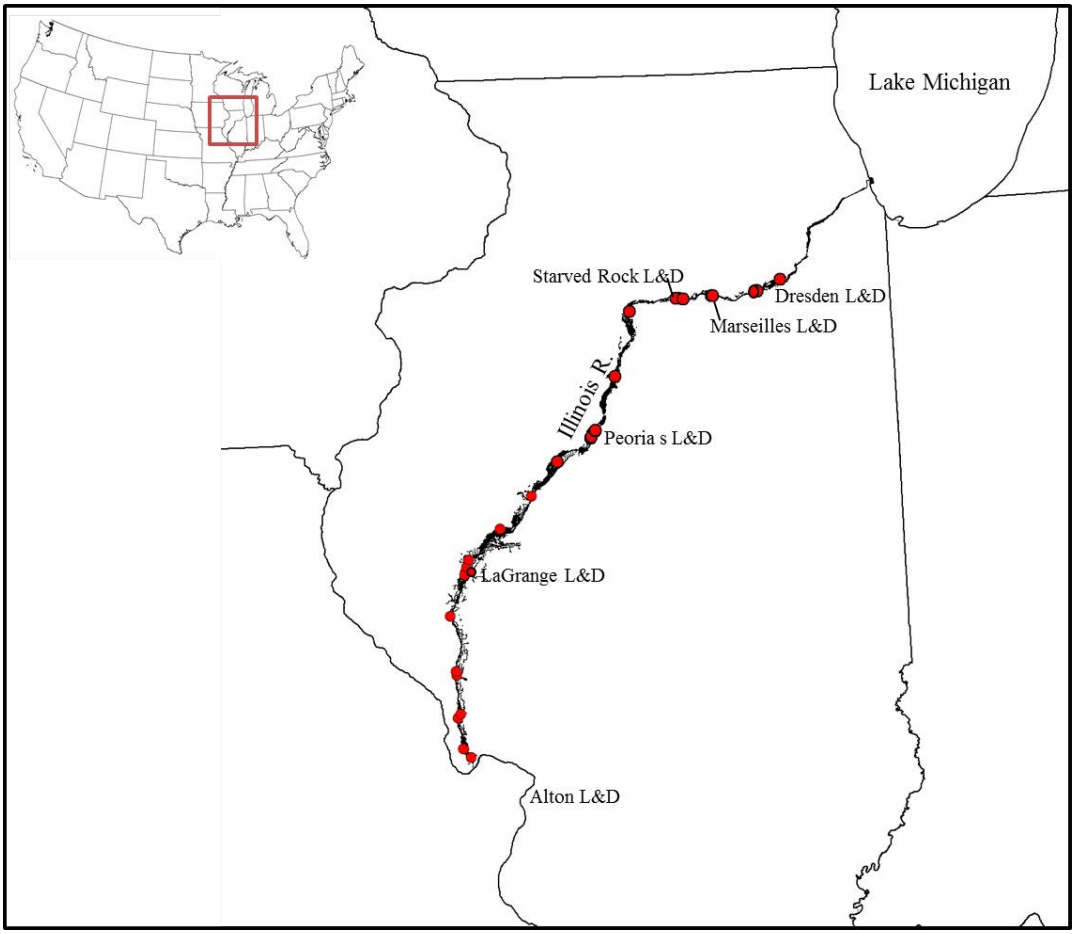

Figure 1. Locations of all active VR2W receivers along the Illinois River.

Figure 2. The red circle identifies the area where 37 individual Asian carp were detected during active tracking conducted in 21 November and 6 December 2012.

Chapter 6:

Identification of natal environment of adult Asian carps in the Illinois River using otolith microchemistry and stable isotope analysis

Greg Whitledge, Southern Illinois University at Carbondale

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

Introduction: Asian carps are known to be reproducing in the Illinois, middle Mississippi, and lower Missouri Rivers. However, the extent to which the Asian carp stock in the Illinois River is derived from recruits from within the Illinois River vs. immigrants from the Mississippi and Missouri Rivers is unknown. Asian carp are also known to use connected floodplain lakes during early life, but the contribution of these habitats to Asian carp recruitment in the Illinois River is also unknown. Knowledge of Asian carp recruitment sources is needed to: 1) assess the degree to which stocks of these species in the Illinois River may be replenished by immigrants from other rivers and the potential need to expand the geographic scope of enhanced commercial harvest efforts, 2) estimate immigration rates for use in modeling stock dynamics, and 3) to 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 and Silver Carp in four reaches of the Illinois River (Alton, LaGrange, Peoria, and upper river). Characterize timing and patterns of inter-river movement for immigrants. Estimate 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 four reaches of the Illinois River (Alton, LaGrange, Peoria, and upper river) during 2010-2012 by electrofishing and trammel netting. 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. 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.

Age-0 Bighead and Silver Carp from the Missouri, Illinois, and upper Mississippi Rivers and fish of known environmental history from other locations (e.g., fish that were known to have been isolated in lakes or ponds) were obtained during 2010-2011 to characterize water-otolith chemistry relationships for Asian carp. These data were necessary to enable interpretation of otolith chemistry data for adult Asian carp of unknown origin that were captured in the Illinois

River. Otoliths from age-0 and known-history fish were analyzed for Sr:Ca and stable oxygen and carbon isotope ratios as described above, except that subsamples for Sr:Ca, $\delta^{18}O$ and $\delta^{13}C$ analysis were obtained from the otolith edge, which reflects a fish's recent environmental history (and thus its capture location).

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, and 2012 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 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.

Analyses of otolith Sr:Ca and $\delta^{18}O$ for Asian carp of known environmental history indicated that there are strong relationships between water and otolith Sr:Ca and $\delta^{18}O$ for Asian carp, consistent with prior applications of this technique to other fish species. Thus, these two naturally-occurring chemical markers in otoliths can be used to identify natal environment of unknown-origin Asian carp collected from the Illinois River.

Three hundred seventy six adult Asian carp (fish of unknown origin; 281 Silver Carp and 95 Bighead Carp) collected from the Illinois River during 2010-2011 were analyzed for $\delta^{18}O$ and $\delta^{13}C$ of the otolith core. Otoliths from fish collected during 2012 are currently being prepared for analysis of $\delta^{18}O$ and $\delta^{13}C$ at SIU; analyses will be completed in February 2013. Only 3% of the fish analyzed to date had otolith core $\delta^{18}O$ and $\delta^{13}C$ signatures indicative of use of riverine habitats during early life. 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 slack-water; near-shore areas within the river represent the predominant nursery habitat for larval and young juvenile Asian carp. The few fish that exhibited evidence of use of floodplain lakes during age-0 were primarily Silver Carp that were captured as adults in the upper river where floodplain lakes are absent; indicating that these fish had immigrated from downriver.

Otoliths from 456 adult Asian carp (260 Silver Carp and 196 Bighead Carp) collected from the Illinois River during 2010-2011 (fish of unknown origin) have been analyzed for Sr:Ca. Otoliths for Sr:Ca analysis from fish collected during 2012 are currently being analyzed at UMass-Boston; analyses will be completed in February 2013. Sixty one percent of adult Silver Carp analyzed to date 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 11-39% of adult Silver

Carp 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 origin to individual fish). Among Silver Carp that were immigrants to the Illinois River, the vast majority originated in the middle Mississippi River; < 2% of the total number of Silver Carp captured in the Illinois River originated in the Missouri River. Immigrants represented a consistent proportion of individuals sampled across all four reaches of the Illinois River (Alton, LaGrange, Peoria, and upper river), indicating that the contribution of immigrants to the Silver Carp stock in the Illinois River is consistent along the river's length. We have also observed (based on changes in Sr:Ca across sectioned otoliths) several Silver Carp that entered, exited, and re-entered the Illinois River from the Mississippi River at multiple times during their life. In contrast, otolith core Sr:Ca indicated that 97% of Bighead Carp analyzed to date originated in Illinois River, with 3% originating in the middle Mississippi River. The distributions of otolith core Sr:Ca values for Silver Carp and Bighead Carp were consistent across fish sizes, indicating that immigrants are not necessarily of a particular size or age (most of the fish analyzed to date were likely age-3 through age-5). Caudal fin clips were obtained from all Bighead and Silver Carp collected during 2012; these fin clips were used by Jim Lamer (WIU) to identify hybrids in 2012 collections. We will use these data to determine whether there are differences in principle natal environments of hybrids vs. parental species.

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 that immigrate into the Illinois River suggests 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. The next step is to continue to monitor the relative abundances of resident (Illinois River origin) and immigrant (Mississippi or Missouri river origin) Bighead Carp and Silver Carp in the Illinois River to determine the effect of enhanced commercial harvest on recruitment sources and dynamics of Asian carp.

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

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

Clark E. Dennis III, Daniel F. Kates, Will Ceijtin, Shivani Adhikari, 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, as 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 the electric barrier system in the Chicago Area Waterway System (CAWS). While the electric barrier system has been effective to date, no non-physical barrier is 100 % effective, 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 redundancy in 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. The 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. 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: Current investigations exploring the use of carbon dioxide gas as a chemical barrier to deter the movement of Asian carp follow two main 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 Asian carp that are small enough to potentially bypass the electrical barrier system.
2. ***Quantify the effectiveness of a carbon dioxide barrier in a field setting***

Objective 1 Methods: The response of early life-stage Asian carp to elevated carbon dioxide was investigated using three different stages of life: 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, experiments were performed for either 30 minutes or 60 minutes at control (0 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 a RNA stabilizing solution and stored until further laboratory processing. Approximately one week later, this same set of experiments was performed on Asian carp fry coming from the same hatching tank the eggs were obtained.

To investigate the response of Asian carp fingerlings to elevated carbon dioxide, two separate but complementary experiments were performed. Fingerlings were obtained and held at the Upper Midwest Environmental Science Center (UMESC) at La Crosse, WI in December 2012. The physiological challenge for fingerling Asian carp largely follows the experiments performed on Asian carp eggs and fry, however a 24 hour acclimation was provided to allow fish to return to resting conditions following netting/handling of fish 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 eggs/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 Silver Carp and Bighead Carp fingerlings were subjected to a behavioral avoidance challenge. Briefly, Asian carp 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, twitch, 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), heat shock cognate 70 isoform 2 (Hsc70-2), glucocorticoid receptor 2 (GR-2), and 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. Samples are currently being prepared for qPCR analysis.

Asian carp fingerlings were tested for their response to elevated CO_2 between 4 December and 10 December, 2012. For the physiological experiment, 10 Silver Carp or Bighead Carp per treatment-duration pair were sampled for three tissues (gill, liver, and muscle) resulting in a total of 360 samples. These samples are currently being prepped for qPCR analysis.

During the behavioral studies, Silver Carp and Bighead Carp fingerlings displayed agitation at approximately 80 mg/L CO_2. Asian carp fingerlings tended to initiate shuttling behavior and leave CO_2 water at approximately 210 mg/L CO_2.

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. This finding is 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 and fish that are small enough to theoretically pass through the electrical barrier unharmed. 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 is 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.

Objective 2 for this study involves the quantification of the effectiveness of a carbon dioxide barrier in a field setting. Discussions have been underway with staff at the Upper Midwest Science Center (UMESC) in La Crosse, WI, about the use of pond facilities and research laboratories for this work. It is currently believed that field trials coupling (a) telemetry to track the movement of free-swimming Asian carp in a pond, and (b) large scale deployments of CO_2 will occur in the summer of 2013. Discussions have also been underway with federal and state agencies (e.g., Environmental Protection Agency) about permitting requirements for large-scale field tests of a CO_2 barrier in a real-world setting (i.e., not in a research facility).

Overall 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 cm) Asian carp, which would help augment potential deficiencies with the existing electric

barrier system. Future work should focus on mode of impact of CO_2, impacts to non-target organisms, and logistics associated with field deployment at large scales.

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 to quantify the impacts of CO_2 exposure on the behavior and stress response of fingerling Silver Carp and Bighead Carp. Data analysis is currently underway. Preliminary analyses indicate that fingerling Asian carp will actively avoid water with CO_2

- Discussions have been ongoing between the University of Illinois and UMESC about field experiments to quantify movement and activity of free-swimming Asian carp in a pond following exposure to CO_2

- Discussions have been ongoing between the University of Illinois and various state and federal agencies (e.g., EPA) about permitting and permission issues related to large-scale field deployments of CO_2 barriers in a remote setting