



2017 Asian Carp Action Plan

Amendment Package

Asian Carp Regional Coordinating Committee

Members of the Asian Carp Regional Coordinating Committee (ACRCC) are committed to the goal of developing and implementing a comprehensive strategy to prevent the introduction and establishment of Asian carp in the Great Lakes. Currently, a primary component for preventing the movement of Asian carp from areas where established in the Mississippi River watershed into the Great Lakes includes a series of electric barriers located in the Chicago Area Waterways System. The following additional strategic control measures and technologies were selected for advancement based on the availability of funding and their respective potential viability to support the mission of the ACRCC of Great Lakes protection from Asian carp:

- Carbon dioxide (CO₂) injected into water is a non-selective (not focused on single species) approach being developed to reduce the threat of Asian carp movement into the Great Lakes. Research has shown that dissolved CO₂ is successful at keeping fish out of specific areas and can be used to reduce upstream movement in controlled environments. This effort will address the engineering requirements for infusing a large volume of CO₂ into a large volume of water to operationalize the use of CO₂ for deterring fish passage. USGS is working with partners to determine how CO₂ and other deterrents might be incorporated into a larger, comprehensive Asian carp control strategy.
- Water jets placed in strategic locations in the Upper Illinois Waterway might be used to successfully flush Asian carp and other fish species that have become entrained between barges as they pass through navigation structures. This effort will assess the effectiveness of water jets as mitigation of fish passage across the electric dispersal barrier system on the Chicago Sanitary and Ship Canal, as a tool to further hinder their movement and spread closer to the Great Lakes. This proposed amendment will allow the development and completion of field testing of water jets as an effective tool for barge entrained fish.
- Electric Barrier IIA of the U.S. Army Corps of Engineers (USACE) Electric Dispersal Barrier System utilizes electrodes to deliver electricity to the water and deter fish away from it. During a recent assessment, USACE determined that corrosion was occurring and replacement of the electrodes was necessary to ensure continued and effective operation of the barrier. This effort will allow for replacement of the high field electrodes at Barrier IIA.
- Underwater sounds have been shown to deter the movement of Asian carp in laboratory studies. This technology can utilize either single or complex sounds located in key areas through which fish may swim. This effort will allow expedited completion of field testing of the technology and its demonstration in a waterway system as a viable control and deterrent for Asian carp.
- Black carp populations in the Upper Mississippi River basin have increased in recent years, demonstrating an additional emerging threat. Data on species range and distribution results primarily from the capture of black carp by commercial fishermen, and traditional gear sampling efforts by resource agencies. This effort will advance the development and use of eDNA technology focused on more readily detecting black carp occurrences in key waterways. This will be critical in areas where populations are yet to become well-established and where early identification can be used for guiding focused control efforts.

This Action Item package is an amendment to the approved 2017 Asian Carp Action Plan and includes new or updated 2017 action items based on additional GLRI funding received for the control and management of Asian carp against their movement into new waterway systems, including the Great Lakes.

22. Field Deployment of Carbon Dioxide Barrier to Deter Asian Carp

Lead Agency: USGS/IL DNR

Other Agencies Involved: University of Illinois Urbana-Champaign, USACE, USFWS, Southern Illinois University

Funding Table:

Funding	Agency Funding	Asian Carp GLRI Funding
FY 2017	\$310,000	\$1,590,000

*This represents a GLRI increase of \$1,100,000

Project Description: Currently, prevention of Asian carp movement from the Mississippi watershed into the Great Lakes rests on a single electric barrier located in the CAWS. Supplemental and redundant deterrent strategies to the electric barrier would improve the efficacy of deterring Asian carp movement into the Great Lakes. As such, chemical barriers that deter fish passage and allow continued river navigation are being developed. Additionally, managers need chemical controls to reduce Asian carp populations and decrease the number of fish attempting to move upstream to further support barrier efficacy.

Some work has been done to define biological limits and potential benchmarks for candidate chemicals that may serve as a non-physical barrier and lethal control of Asian carp. One candidate barrier chemical that has received a great deal of attention is carbon dioxide gas (CO₂). Adding CO₂ to water has two main effects: (1) a reduction in pH caused by the formation of carbonic acid (a weak acid), and (2) elevation of dissolved CO₂ (hypercarbia). While the exact mechanism that induces avoidance and toxicity in fish exposed to CO₂-enriched water has not yet been defined, it is believed that CO₂ functions by disrupting normal respiration and acid-based regulation. It is important to note that additions of CO₂ do not function as a ‘bubble curtain’ (not a physical obstruction), CO₂ does not deter movement by causing hypoxia, and the inevitable change in pH associated with elevated CO₂ is not sufficient to cause fish to move. Rather, it is believed that fish have CO₂ receptors in their gills and are able to sense CO₂ in the water, and it is the presence of a physiologically unacceptable concentration that causes fish seek fresh water. Additionally, CO₂ does not appear to be species-specific, with most fishes affected in a similar fashion; a CO₂ barrier would therefore likely prevent the movements of non-target fishes as well. In addition, CO₂ appears to affect smaller fishes as well as larger ones. Collectively, CO₂ would benefit Asian carp management by denying access to critical habitat, blocking upstream movement, reducing overwinter survival, and pushing fish into locations to promote harvest and removal.

Summary of Actions to Date: To date, multiple laboratory and pond studies have been completed with Asian carp and non-target species. Discussions with the USEPA regarding regulatory framework for research applications of CO₂ in open water applications, including barrier operations, have been initiated. The physiological response of native mussels to CO₂ study has been completed under the guidance of Section 7 consultation by the USFWS. Also, the U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (USACE) – Engineer Research and Development Center are proposing to evaluate the engineering design requirements of a CO₂ barrier by temporarily installing a CO₂ barrier at the auxiliary lock of Lock and Dam 14 near Bettendorf, IA in FY18. Proposed actions were briefed to the USACE

Rock Island District in May requesting study approval. Since the May 2017 briefing, conceptual manifold designs have been developed by engineers at the University of Wisconsin – Platteville and physical testing of manifolds is ongoing and final design recommendations will be completed by mid-August. Additionally, USGS has completed hydraulic assessments and established water quality stations at the auxiliary lock. A follow-up briefing with the Rock Island District requesting formal study approval is scheduled for SEP17 to allow engineering and design to progress and inform navigation concerns. The USGS has addressed many of the concerns and requirements raised by the Rock Island District and will continue to work with the Rock Island District to successfully implement this study. Lastly, numerous manuscripts have been developed and have been published in scientific journals.

The following work was completed in 2016:

- Completed evaluations of CO₂ injected under-ice to enhance overwinter mortality of invasive cyprinids (Silver Carp, Bighead Carp, Grass Carp, and common carp).
- Completed evaluations to determine CO₂ concentrations that induce avoidance and immobilization behaviors with Silver Carp and Bighead Carp.
- Completed evaluations to determine the effect of temperature on Silver Carp and Bighead Carp movement in response to elevated CO₂.
- Completed evaluations of CO₂ injection methods in laboratory flumes to determine gas-transfer efficiency (collaboration with University of Wisconsin – Platteville engineering students).
- Completed acute toxicity evaluations on the effects of CO₂ on non-target juvenile mussels.
- Completed chronic toxicity evaluations on the effects of CO₂ on non-target juvenile mussels (including federally endangered species).
- Participated in CO₂ Advisory Group made up of federal and state agencies to develop plan for transitioning from research to management applications.
- Published a peer-reviewed manuscript describing the avoidance responses of Silver Carp and Bighead Carp to a CO₂ barrier in outdoor ponds (Cupp and others 2016, Canadian Journal of Fisheries and Aquatic Sciences).
- Published a peer-reviewed manuscript describing the swimming responses of invasive carp and native fishes to CO₂ (Donaldson and others 2016, Transactions of the American Fisheries Society).
- Published a peer-reviewed manuscript describing the effects of CO₂ on juvenile mussels (Waller and others 2016, Environmental Toxicology and Chemistry).

Proposed Actions for FY 2017:

- Develop comprehensive planning assessments for deploying CO₂ at a lock or approach channel to deter Asian carp movement.
- Conceptual manifold designs developed by engineers at University of Wisconsin Platteville
- Complete testing of manifold designs.
- Complete hydraulic assessment and establish water quality stations in an auxiliary lock at Lock and Dam 14.
- Conduct field studies to demonstrate potential management applications:
 - Apply CO₂ to block Asian carp access to backwater areas of the Illinois River
- Continue to evaluate the behavioral responses of Asian carp to CO₂ enriched water.
 - Determine the movement of Asian carp in response to gradients of elevated CO₂ in flowing water
- Continue to evaluate the effects of CO₂ enriched water on non-target species.
- Publish a report and associated data describing the use of CO₂ injected under-ice to enhance overwinter mortality of Asian carp.

- Publish a report and associated data describing the effects of temperature on the behavioral responses of Asian carp to elevated CO₂.
- Publish a report and associated data describing the effects of elevated CO₂ on common and endangered mussels (non-target impacts).
- Complete studies as needed to complete USEPA registration CO₂ as a control agent in limited open-water application sites.
- Expand studies with potential non-target species (such as banded killifish and caddisfly) to address USFWS Section 7 ESA-consultation data requirements of CO₂ as a control agent for emerging locations.

Potential Out-year Actions (Subject to Future Appropriations):

- Conduct field studies at lock or approach channel to deter the movement of Asian carp.
- Conduct field studies applying CO₂ as lethal control for Asian carp.
- Conduct field studies to support Asian carp removal efforts.
- Assist management agencies that plan to deploy CO₂ as a control agent in open-water applications.
 - To block/deter Asian carp movement at key locations
 - To enhance Asian carp fishing/removal efforts
 - To administer as lethal control for Asian carp
- Continue to develop studies as needed to complete USEPA registration of a CO₂ barrier or the use of a CO₂ as a control agent in limited open-water application sites.
- Complete studies to address USFWS Section 7 ESA-consultation data requirements of a CO₂ barrier or the use of a CO₂ as a control agent in limited open-water application sites.
- Respond to USEPA or state regulatory agencies review of data submitted to register CO₂ as a barrier or as a control agent in limited open-water application sites.
- Respond to FWS review of data submitted to address Section 7 ESA consultation of the use of CO₂ as a barrier or as a control agent in limited open-water application sites.

Expected Completion Date for Project:

- Transition to management agencies can occur at any time and future research is tailored to supporting management decisions and implementation.

Expected FY 2017 Milestones:

- Demonstrate field application of CO₂ to deter fish movement.
- Comprehensive planning assessment for CO₂ at lock/approach channel.

Outcomes:

- Define the effectiveness of CO₂ as an Asian carp management tool
 - Barrier/deterrent
 - Lethal control
 - Enhance removal efforts
- Provide recommendations to management agencies on the operating conditions for applications listed above

Potential Hurdles:

- Capacity of the CO₂ infusion system to evenly disperse CO₂-infused water within an uncontrolled flow environment to maintain target concentrations.
- Potential effects of carbonic acid on in-water navigation/control structures.
- Potential effects of CO₂ on non-target species caused by non-selectivity.

44. Field Testing of Water Jets to Mitigate Barge Entrainment of Fish

Lead Agency: USACE

Agency Collaboration: USACE, USFWS, USGS

Funding Table:

Funding	Agency Funding	Asian Carp GLRI Funding
FY 2017	\$0	\$675,000

*This represents a GLRI increase of \$100,000

Project Explanation: Previous laboratory and field studies have shown that commercial barge tows operating within the CSSC can produce residual water currents and forces that can entrain and potentially transport fish across the electric barrier system. Laboratory studies completed in 2016 in a flume model indicate that water jets can be effective at removing entrained fish from the vicinity of northbound barge tows.

This project will develop and complete a field testing program to determine the feasibility and effectiveness of water jets for mitigation of entrainment. The tests will be conducted in the CSSC in the vicinity of the electric barriers to the extent possible. The intent is to temporarily install a water jet system in the water of the canal, place fish or a model for fish in areas near a barge tow where they are or will become entrained, and then monitor what happens as the barge tow passes over the water jets. The movements of the fish will be monitored by cameras. Water velocities and flow patterns will be recorded by flow meters. Some control runs with the water jets turned off will also be completed for comparison.

Summary of Actions to Date: In 2011, the U.S. Army Engineer District, Chicago (LRC), requested the USACE Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), to determine if commercial navigation could cause or facilitate transport of Asian carp past the protective electric barriers at some time in the future. It was hypothesized that currents generated by moving vessels or the vessel structure itself could inadvertently entrain fish, where they would be carried along with the vessel across the electric dispersal barriers. Once passed, the fish would be free to swim further upstream and potentially on to Lake Michigan.

A 1:16.7 scale physical model with remote-controlled towboat and barges was used to evaluate the interactions of vessel, fluid motions, and nearly neutrally buoyant objects (model Asian carp) under a variety of vessel speeds and barge configurations typical of the CSSC in the vicinity of the electric barriers (Bryant et al. 2016). The primary tow configuration consisted of six barges traveling in a two-wide by three-long flotilla. Other configurations, including a one-wide by three-long configuration, were investigated as well. Four of the barges had a rake at one end and the other two were boxed at both ends. A number of barge configurations were investigated including rake-box, rake-rake, and box-box connections.

To conform to the natural flow in the CSSC the experiments were divided into northbound (upstream) and southbound (downstream) directions, which placed the tows in different hydrodynamic regimes. For southbound traffic, the return velocity was shown to be most relevant for model fish transport. Northbound traffic produced transport by four different modes. The modes that transported fish the greatest distances were entrainment in vortices that make up the wake flow, and entrainment in the vortices that exist within voids in the barge configurations.

Subsequent field tests completed by USFWS with support from USACE and USGS have shown that transport of fish by barge tow entrainment is possible in the CSSC at the barriers.

The previous physical model that was used in the earlier laboratory study was updated and tests were completed to investigate mitigation measures to remove or dislodge entrained Asian carp and to determine the efficacy of such measures.

The flushing alternatives were designed to remove fish before crossing the barrier and applied to northbound tows. The design included a manifold placed on the bottom of the canal with a series of upward facing jets that impinged on the bottom of the barge during passage. A number of trial tests with different manifold and jet configurations were conducted to determine which method removed the greatest number of fish. The results indicated that a jet oriented at 67.5 degrees from the horizontal with a 12 inch nozzle had a minimal effectiveness of 100 percent for a two by three barge configuration traveling at 2.5 mph. At higher vessel speeds (4 – 5 mph) the jets were unable to remove all fish. The main contributing factor to the lower minimum effectiveness was the increased vessel speed, which reduced the exposure time so the model fish were not subjected to the flushing action long enough to be removed from the barge junction.

Proposed Actions for FY 2017:

- Develop a scope of work (SOW) to test the use of water jets in the field. The SOW will include a detailed description of methodologies and expected products and outline in more detail the schedule and cost requirements for the project.
- Acquire, construct, and test the necessary test apparatus including jet nozzles, hoses, pumps, and piping.
- Install the water jet equipment in the canal and complete test runs with barge tows. A brief.
- Prepare a brief memorandum report summarizing the work completed and any immediately available results shortly after completion of the testing.
- Begin preparation of a final report summarizing in detail the test methods and results.

Proposed Actions Potential Out-year Actions (Subject to Future Appropriations): Complete the final report.

Deliverables: The FY 2017 deliverables will be the detailed SOW, completion of field testing, and the initial testing summary report.

Expected Completion Date for Project: The expected completion date is the second quarter of FY 2018.

Expected Milestones:

- First Quarter 2017 – Completion of SOW
- Second Quarter 2017 – Necessary equipment acquired and initial testing of water jet apparatus completed
- Fourth Quarter 2017 – Completion of test runs with barge tows. Completion of initial summary report.

Outcomes/Outputs: The output will be the final report describing the effectiveness at disrupting entrainment of the various water jet operating scenarios tried and recommending if any are suitable for long-term implantation at the CSSC barriers site. Considerations for future longer-term deployment of water jets will be highlighted.

Potential Hurdles:

- Methodology for implementation of a water jet system in the canal (hasn't been attempted before)
- Coordination with navigation.

68. Electric Dispersal Barrier Electrode Replacement

Lead Agency: USACE

Agency Collaboration: USCG, USFWS, MWRD

Funding Table:

Funding	Agency Funding	Asian Carp GLRI Funding
FY 2017	\$0	\$3,500,000

*New Action Item

Project Explanation: The electric dispersal barriers are located in the Chicago Sanitary and Ship Canal (CSSC), which is a man-made waterway creating the only continuous connection between Lake Michigan and the Mississippi River basin. The dispersal barrier system was developed to prevent the spread of invasive fish species between these watersheds.

Operation of the first barrier (Barrier I) by USACE began in April 2002, demonstrating a new technology for preventing the spread of aquatic nuisance species.

Barrier I, which is located at river mile 296.5 in Romeoville, IL, is formed of steel cables that are secured to the bottom of the canal. A low-voltage, pulsing DC current is sent through the cables, creating an electric field in the water. The electric field is uncomfortable for fish and they do not swim across it.

In 2004, USACE initiated construction of a permanent barrier (Barrier II) to prevent the migration of fish, including Asian carp, between the watersheds. Barrier II, which is located 800 to 1,300 feet downstream of Barrier I, also uses a pulsed electric field, but includes several design improvements identified during monitoring and testing of Barrier I including the use of 5"x5" steel billets for the electrodes instead of cables. The steel billets were projected to have a life span of 25 years. Barrier II is able to generate a more powerful electric field over a larger area and was implemented in two halves, known as Barriers IIA and IIB. Barrier IIA began full-time operation in 2009. Barrier IIB became fully operational in 2011.

Summary of Actions to Date: In January 2017, a USACE dive team conducted a visual inspection of the electrodes, examining their condition at 5-foot intervals. Results of the inspection indicate the electrodes are corroding faster than expected and require replacement.

FY 2016 Actions: None.

Proposed Actions for 2017:

- Complete an underwater inspection of in-water structures in January 2017.
- Initiate design of replacement electrodes for Barrier IIA's narrow (high field) array.

Proposed Actions Potential Out-year Actions (Subject to Future Appropriations):

- Complete plans and specifications for IIA narrow (high field) array electrodes
- Award a construction contract
- Complete installation of IIA narrow (high field) array electrodes

What Is Deliverable for this Funding (for each Fiscal Year): Contract plans and specifications for electrode replacement, new electrodes at Barrier IIA.

Expected Completion Date for Project: The expected completion date is the first quarter of FY 2019.

Expected Milestones:

- Fourth Quarter 2017 – Initiate design work

Outcomes/Outputs: Outputs include a reduction in the risk of upstream fish passage due to malfunction of the Barrier system. Replacement of the electrodes eliminates a potential pathway of system failure.

Potential Hurdles:

- Construction delays due to inclement weather or undesirable flow conditions.
- Coordination with navigation.

74. Field Deployment of Underwater Sound to Deter Asian Carp

Lead Agency: USFWS

Other Agencies Involved: USGS, USACE, University of Minnesota, University of Minnesota-Duluth, Kentucky Department of Fish and Wildlife Resources, Iowa Department of Natural Resources

Funding Table:

Funding	Agency Funding	Asian Carp GLRI Funding
FY 2017	\$300,000	\$1,000,000

*New Action Item

Project Description:

Ensuring the prevention of Asian carp movement from established downstream source populations in the Mississippi River watershed into the Great Lakes currently relies heavily on the efficacy and ongoing operation of an electric dispersal barrier (EDB) system located in the Chicago Area Waterway System (CAWS) near Chicago, IL, as well as non-structural control methods, such as intensive commercial harvest of adult fish downstream of the EDB. Supplemental deterrent control technologies that target all life stages of Asian carp (i.e., larval, juvenile and adult fish) would add important layers of defense to augment and add redundancy to the EDB, further reducing the risk of Asian carp introduction and establishment in the Great Lakes Basin. The need for deployment of multiple and complementary control layers is supported by results in the Great Lakes Mississippi River Interbasin Study, which identified the upper Illinois Waterway and the CAWS as the singular highest-priority potential pathway of introduction for Asian carp into the Great Lakes via the Mississippi River Basin.

Additionally, other large river systems in the Midwest are experiencing Asian carp range expansions. In many areas, locks and dams act as structural deterrents to carp passage, but these structures also provide locations where additional deterrent measures can be established. To that end, a suite of deterrent technologies are being developed and evaluated for potential implementation at strategic locations or “pinch points” to prevent further upstream movement and range expansion. Development and deployment of these technologies supports the goals and objectives of the national “Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States” (National Plan), and the mission of the bi-national Asian Carp Regional Coordinating Committee (ACRCC). Additionally, new non-lethal Asian carp deterrents are increasingly being sought by agencies due to their lessened effects on non-target native aquatic species and reduced overall environmental impact.

In addition to chemical barriers that deter fish passage and allow continued river navigation, acoustic barriers using sound as a deterrent are also being developed. Use of sound deterrents directly supports the goals of the National Plan and builds on outcomes from a recent interagency acoustic technical workshop in 2016. Relative to other deterrents, complex sound technology is comparatively inexpensive, has the least negative potential impacts to native fishes, requires low environmental compliance, is low risk to human health, and is temporary, modular and transferrable. Managers need more field-level information on deterrent strategies *where Asian carps are established* to determine the most effective suite of controls to reduce Asian carp populations and decrease the number of fish attempting to move upstream to further support barrier efficacy.

Due to their physiology, bighead and silver carps have a greater sensitivity to sound pressure and a wider hearing bandwidth for sound. Empirical evidence from laboratory and pond studies has shown that complex underwater sound stimuli can alter or disrupt the behavior of both silver and bighead carps. Building off of these studies and deploying experimental acoustic structures at critical passage points in the Upper Mississippi River (UMR) and Ohio River (OHR) Basins will help managers understand the effectiveness of acoustic deterrents where Asian carp populations are established and will evaluate potential for the technology to be deployed in other locations to prevent upstream migration and slow the range expansion of Asian carps.

Summary of Actions to Date: To date, multiple laboratory, test-pond studies, and controlled field trials have been completed with Asian carp and non-target species. Though field studies have not yet been conducted where Asian carps are established, interjurisdictional coordination bodies (e.g., ACRCC, MICRA) across the UMR, Great Lakes-Illinois Waterway, Missouri River, and OHR Basins have identified the implementation and further field testing of acoustic deterrent technology as a priority for slowing the advance and population growth of Asian carps in the Midwest.

This project complements ongoing acoustic research efforts of the USGS and will facilitate the overall evaluation of acoustic deterrent technology as an effective tool for Asian carp management, prevention and control. Researchers and managers from USFWS, USGS, USACE, States and Universities have compiled an interagency team to accomplish the experimental deployment of an acoustic deterrent where Asian carps are established.

Locations for potential deployment of an acoustic array are being evaluated by the interagency team of resource managers. Potential sites include LD19 at Keokuk, IA (UMR) and the Kentucky Dam or Barkley Dam (Cumberland River) in the OHR Basin. The team will develop evaluation criteria for site selection and work with federal, state and academic partners to purchase and deploy sound equipment in the water. Basic criteria for site determination will be based on: the biological characteristics of the present carp population, structural characteristics of the passage point (i.e., lock and dam), and presence of telemetry infrastructure at the location. Of special consideration will be the impact to native aquatic connectivity, and potential mitigative measures will be discussed. Specific measureable goals and objectives of the study with a detailed timeline will also be deliberated. The team will monitor and assess the feasibility and efficacy of the technology using telemetry, sonar, and other assessment methods. In the event the technology is needed in other key locations to provide the best opportunity for prevention, it could be transferred from these test locations to other sites.

Proposed Actions for FY 2017:

- Develop comprehensive planning assessments for deploying complex sound at a lock or approach channel to deter Asian carp movement.
- Determine sound technology specifications

Proposed Actions Potential Out-year Actions (Subject to Future Appropriations):

- Develop monitoring and evaluation methodology
- Installation of acoustic deterrent equipment
- Implement monitoring protocols

Potential Out-year Actions (Subject to Future Appropriations):

- Refine existing array based on additional research that aims at refining sounds or developing additional deterrent techniques.
- Transfer and evaluate sound array at alternate locations in the IWW, UMR or OHR.

Expected Completion Date for Project:

- Field deployment targeted for late FY2018- early FY2019, though expedited coordination and communication among the team is essential to achieving this goal.

Expected FY 2017 Milestones:

- Continued coordination among interagency team
- Technology, location, study design parameters evaluated.

Outcomes:

- Define the effectiveness of a particular underwater sound, per this study design, as an acoustic deterrent for Asian carp where they are established.
- Provide results of this study to other management agencies (cross-basin) on the efficacy of this underwater sound technology as a deterrent; discuss management implications for future prevention and control techniques.

Potential Hurdles:

- Potential impacts to in-water navigation, operators, or control structures and coordination with navigation industry.
- Potential effects of underwater sound on non-target species and native aquatic connectivity.
- Permitting requirements for equipment installation and operation.
- Primary back up sources of power for equipment operation.
- Weather delays due to flooding or altered river discharge (more or less than average).
- Delays with product development, placement, or engineering constraints.

75. Advancing eDNA and Other Genetic Tools for Black Carp

Lead Agency: US Army ERDC Environmental Laboratory, USACE

Other Agencies Involved: USFWS

Funding Table:

Funding	Agency Funding	Asian Carp GLRI Funding
FY 2017	\$300,000	\$300,000

*New Action Item

PROJECT Explanation:

Improving eDNA Capabilities

With the growing numbers of black carp captured in the Upper Mississippi River Basin, it is apparent that populations of this invasive species may be on the rise in the region. In some cases, newly establishing populations may be coming out of a slow growth phase (*see* figure on right) and have or will soon arrive at a demographic “sweet spot”, after which the populations will grow and expand much more rapidly. Another scenario that would be common to invasive species is that black carp populations may have recently experienced improved local adaptation and are beginning a more rapid population expansion. Considering the potentially dire impacts of molluscivorous black carp on native mussels and other mollusks, tracking changes to the extents of the black carp invasion in North America would be a critical need. This is as much the case for the Upper Mississippi River and, eventually, Great Lakes, as it is for anywhere in North America. Similarly, determining the current limits of black carp populations would allow resource managers and other stakeholders to implement control measures during a period when the species is more vulnerable (than at later stages of invasion).

It is clear that at current population levels, black carp eDNA will not be detected using the same approaches as have been used for other invasive carp. Considering the critical need to track the expansion of black carp into new reaches of the Upper Mississippi River Basin, particularly into the Illinois River system and Great Lakes region, we recommend additional efforts to optimize eDNA techniques and monitoring strategies for black carp.

Developing Protocols for Rapid Estimation of Juvenile Carp Numbers in Large Minnow Collections

Large collections of minnows are frequently collected during fish surveys in the Upper Mississippi and associated drainages. The determination of how many fish in the collections are juvenile black carp is highly laborious and, for some ages (first few months), very difficult and potentially error-prone. Genetic methods based on copy numbers for Asian carp unique markers, or even genetic diversity in other black carp markers, could be used for more efficient estimation of the proportion of black carp in such collections.

Characterizing Trends in Outbreeding

Also, as the numbers of black carp (*Mylopharyngodon piceus*) captured in natural waters continue to grow, it is important to understand the breeding parameters of those feral populations. When a species is rare, the low probability of encountering suitable mates (the Allee effect) can curb population growth. Thus, it would be helpful to know if recently captured cohorts of black carp come from a single, small or large set of parents. If only a few parental fish are generating black carp populations, then fish removal with traditional gears can contribute to Allee effects, minimizing population expansion. Populations

derived from a small set of parents will also suffer high levels of inbreeding and will be prone to extinction if juvenile mortality is high and parental fish are extirpated. Understanding the breeding pools for black carp populations will greatly benefit our understanding of how the population is growing, better define its vulnerabilities, and provide information on how to best combat this invasive species.

We use existing microsatellite DNA markers (Guo et al. 2009, King et al. 2011) to estimate the *minimum number of parents*, the *effective number of breeders* (N_b). These data will be combined with similar analyses of young-of-the-year (YOY) carp captured conducted by USFWS WGL to characterize changing reproductive parameters of black carp populations and extrapolate basic population size and outbreeding rate trends.

Summary of Actions to Date: NA

Proposed Actions for 2017: We propose to test these various optimization strategies in support of Objectives 1, 3, 6, and 9 of the Draft Black Carp Strategy.

Improving eDNA Capabilities

There are several measures that could be attempted as part of such optimization. A key data gap that is required to determine what strategic directions to take is the structural nature of black carp eDNA (e.g., unprotected strands, encapsulated in mitochondria, contained in cells). For example, if black carp eDNA is predominantly found in intact cells, then larger mesh filters could be used that allow greater volumes of water to be sampled. Efforts in 2017 would include:

- Experimentally determine the relative contribution of different size fractions of water particulates to total black carp eDNA using replicated trials with water samples from locales known to be utilized by juvenile fish.
 - Where possible, ERDC will share samples with USFWS WGL who are conducting outbreeding studies of YOY black carp.

It may be that more efficient eDNA sampling for black carp will simply be a function of sampling the right habitats during the correct seasons. To that end, in 2017 we will:

- Identify known mussel beds within Upper Mississippi Basin that are within known range of black carp, as well as mussel beds in lower Illinois River.
 - Likewise use existing data and local knowledge to identify sites with heavy Dreissenid mussel infestations.
- Compile all known information on black carp spawning.
- Test different sampling apparatuses for efficiently taking near-bottom and sediment eDNA samples.

Developing Protocols for Rapid Estimation of Juvenile Carp Numbers in Large Minnow Collections

- Compare multiple existing black carp eDNA qPCR markers for strength of correlation between black carp biomass and estimated eDNA copy number
 - Start with simple tissue samples (different masses)
 - Calculate marker efficiency for multiple replicate samples (same fish) and for different black carp.

Characterizing Trends in Outbreeding

- Collect tissue or DNA samples from as many adult (> 1 year) black carp collected in North America as possible.

- Genotype all viable black carp samples at 16 microsatellite markers currently being used by WGL for YOY fish.
- First-order (smaller sample size, limited geography) reconstructions sib/half-sib clusters and estimate MNB for each locale+age cohort.
 - Compare (and plot) MNB estimates among locales and age groups within locales.
- First-order (smaller sample size, limited geography) using the linkage-disequilibrium approach to estimate N_b for all locale+age cohorts and N_e for all locale populations.
 - Compare (and plot) N_b and N_e estimates among locales and age cohorts within locales.

Proposed Out-year Actions (Subject to Future Appropriations):

Improving eDNA Capabilities

- Conduct near-bottom eDNA sampling over mussel beds and a nearby random locations (not mussel beds)
- Compare eDNA results from the different classes of locale.

It may be that more efficient eDNA sampling for black carp will simply be a function of sampling during times of the year when black carp eDNA is most abundant. To that end, in 2018 the following is planned:

- Determine, based on existing knowledge base, when black carp are most active in mating and reproduction
- Conduct eDNA sampling during the spawning and mating seasons, when fish activity and metabolic rates may be highest.

Depending on observations on the nature of black carp eDNA, greater volumes of water might be effectively assayed using beads or silicates that bind free DNA.

- Experiment with use of biotinylated DNA sequence-specific probes, immobilization of captured DNA-biotin moieties on magnetic beads, and magnetic bead separation.
- Experiment with high salinity solutions and eDNA binding to silicates.
- Write final report on optimal eDNA sampling protocols for black carp

Developing Protocols for Rapid Estimation of Juvenile Carp Numbers in Large Minnow Collections

- Compare best (i.e., best correlation between copy number and biomass) markers for effective correlation between eDNA copy number and numbers of black carp juveniles in minnow collections of two different age classes.
- Compare whether a ratio of all fish eDNA (fish-specific qPCR marker) to black carp eDNA provides reliable estimate of proportion of minnows that are black carp.
- Experiment with different washing protocols (e.g., ethanol, lysis solution, etc.) for obtaining DNA from minnow collections.
- Write final report on estimating proportions of black carp in minnow collections.

Characterizing Trends in Outbreeding

- Incorporate tissue or DNA samples from ANY adult (> 1 year) black carp collected since 2017 collection.
- More refined reconstructions of sib/half-sib clusters and estimate MNB for each locale+age cohort.
 - Compare (and plot) MNB estimates among locales and age groups within locales.
- Use linkage-disequilibrium approach to estimate N_b for all locale+age cohorts and N_e for all locale populations.
 - Compare (and plot) N_b and N_e estimates among locales and age cohorts within locales.

- Write final report describing outbreeding (i.e. parentage, relatedness, effective population size) trends in different breeding pools and their trends in different locales in the upper Mississippi river basin.

Expected Completion Date for Project: 12 months after receipt of funding

Expected FY 2017 Milestones:

- Report on levels of eDNA association with different water particle size fractions for YOY black carp
- Report on locales and time periods with expected higher likelihoods of black carp eDNA detection in Illinois River and select other Upper Mississippi River Basin drainages, based on:
 - Presence of native mussel beds and significant Dreissenid mussel
 - Known patterns in spawning behavior for black carp populations (native and invaded ranges)
- Report on tests of potential approaches and apparatuses for sampling sediment for black carp eDNA
- Report on comparative accuracy of biomass prediction for different eDNA markers for black carp
- Genotypes and first-order population genetic characterizations for up to 50 recently-collected adult black carp from at least two locales.

Outcomes:

- A better understanding of directions to pursue in strategically adapting eDNA sampling and monitoring to unique aspects of black carp biology and natural history.
- Quantitative comparisons of the utility of different black carp qPCR markers for estimating carp biomass, with an eye to future applications in determining black eDNA abundances in aquatic systems, in large minnow collections, etc.
- A better understanding of recent patterns in black carp outbreeding and gene flow.

Potential Hurdles:

- Lack of access to multiple streams, ditches, etc. holding YOY black carp could limit the variance encountered and, therefore, the applicability of findings across wide geographic range.
- If black carp behave significantly differently in US than they do elsewhere (e.g., China), then we may have little predictive power to guide sampling design.
- qPCR estimates of biomass may be wildly variable, even with relatively simple samples like muscle tissue.
- The fewer recently-captured black carp that we are able to access for genotyping, the less powerful our outbreeding and gene flow estimates will be.

2017 Action Plan Funding Matrix

FY 2017 GLRI Project Funding*

#	Title	FY 2017 (\$)
1	Great Lakes Mississippi River Interbasin Study (GLMRIS) - Brandon Road	0
2	Lab Experimentation and Modeling to Quantify Response to CO2 in a Flowing Environment	\$450,000
3	Operation and Maintenance of Barriers	\$0
4	Barrier I Constuction	\$0
5	Telemetry - Barrier Efficacy Evaluation	\$0
7	Monitoring and Response Team Support	\$150,000
39	Ohio-Erie Canal Pathway Closure Assessment	\$1,500,000
44	Field Testing of Water Jets to Mitigate Barge Entrainment of Fish	\$675,000
45	Field Deployment of Barriers at Brandon Road Lock	\$685,000
46	Asian Carp Swim Speed Study	\$0
47	H & H Support for Eagle Marsh II	\$25,000
65	Electric Field-Based Aquatic Nuisance Species Dispersal Barrier: Development and Implementation of an Alternating Current Electric Dispersal Barrier	\$477,500
68	Electric Dispersal Barrier Electrode Replacement	\$3,500,000
73	GLMRIS Program Management	\$0
	Subtotal	\$7,462,500

6	Great Lakes Asian Carp Monitoring Program	\$350,000
7	Monitoring and Response Team Support	\$820,000
8	Barge Entrainment and Interaction Study	\$400,000
9	Hydro-Acoustic Assessment of Lock Mediated Fish Passage in the Upper Illinois River	\$0
11	Program Capacity for eDNA Sampling	\$0
12	Fisheries Capacity for eDNA Processing and Technology Refinement	\$0
14	Asian Carp Strategic Communications Plan and Website Operation and Maintenance	\$200,000
16	Registration of Microparticle Technologies	\$75,000
17	Registration of Carbon Dioxide Technologies	\$75,000
43	Program Support for Asian Carp Activities	\$75,000
48	Black Carp Genetic Analysis	\$250,000
49	Analysis of Grass Carp in the CAWS	\$120,000
50	Black Carp Assessment: CAWS and UMRB	\$75,000
51	Mass Removal and Monitoring of Juvenile Asian Carp	\$120,000
52	Barrier Defense Using Novel Gear	\$100,000
66	Predictive Model for Identifying Probability/Risk of Barges Entraining Asian Carps	\$100,000
67	Genomic Mapping of Bighead and Grass Carp to Aid in Genetic Surveillance and Potential Genetic Control Efforts	\$60,000
74	Field Deployment of Underwater Sound to Deter Asian Carp	\$1,000,000
75	Advancing eDNA Sampling and Other Genetic Tools for Invasive Black Carp	\$300,000
	Subtotal	\$4,120,000

16	Registration of Microparticle Technologies	\$100,000
17	Registration of Carbon Dioxide Technologies	\$150,000
18	Development of Grass Carp Control Technologies	\$325,000
19	Assessment of Hydraulic and Water-Quality Influences on Waterways to Develop Control Options	\$300,000
20	Characterization of Brandon Road Lock for Barrier Implementation	\$350,000
21	Use of Seismic Technology to Divert and Eradicate Asian Carp	\$0
22	Field Deployment of Carbon Dioxide Barrier to Deter Asian Carp	\$1,590,000
23	Developing Targeted (Microparticle and Piscicide) Control Systems	\$500,000

FY 2017 GLRI Project Funding*

	#	Title	FY 2017 (\$)
USGS	25	Use of Acoustic Technology to Determine Behavior	\$0
	26	Improving Molecular Techniques for Monitoring, Biomass Estimation, and Correlation with Live Fish	\$0
	27	Integrated Pest Management Program	\$1,590,000
	45	Field Deployment of Barriers at Brandon Road Lock	\$160,000
	53	Use of Complex Sound to Alter Behavior of Asian Carp	\$217,000
	54	Development of Chemical Methods for Control of Aquatic Invasive Species during Lock Operations (Previously Hot Water, Chlorine and Ozone Use for Lock Treatment)	\$100,000
	55	Communication and Demonstration of New Technologies for Control and Monitoring	\$30,000
	56	Black Carp Control, Bait, and Attractant Use	\$80,000
		Subtotal	\$5,492,000
IL DNR	30	Enhanced Monitoring Above and Below Electric Barriers	\$2,000,000
	31	Illinois River Stock Assessment/Management Alternatives	\$300,000
	32	Contract Fishing for Asian Carp Detection and Removal	\$1,400,000
	35	Use of Improved Gear and Novel Designs at Brandon Road	\$150,000
	37	Community Action Initiatives to Increase Awareness, Surveillance, and Enforcement of Unlawful Live Asian Carp	\$300,000
	64	Monitoring Black Carp Population Front in Illinois Waterway and Middle Mississippi River	\$0
		Subtotal	\$4,150,000
ODNR	38	Killbuck Creek Pathway Closure Assessment	\$500,000
	39	Ohio-Erie Canal Pathway Closure Assessment	\$0
	59	Development of Grass Carp Response Capabilities in Ohio	\$100,000
		Subtotal	\$600,000
USCG	40	Manage Waterway Traffic in Support of Asian Carp Control Activities	\$0
	41	Brandon Road Lock and Dam Risk Assessment	\$200,000
	42	Electric Barrier Construction and Operation Risk Assessment	\$200,000
		Subtotal	\$400,000
NOAA	61	Food Web Modeling to Support Risk Assessment of Asian Carp in the Great Lakes	\$159,590
		Subtotal	\$159,590
MIDN R	60	Grass Carp Eradication in Western Lake Erie	\$150,000
		Subtotal	\$150,000
NPS	71	Develop and Implement Education Materials and Lesson Plans in Coordination with Teachers to Further the Asian Carp Response in the Midwest	\$75,000
		Subtotal	\$75,000
USEPA	43	Program Support for Asian Carp Activities	\$290,910
	69	Facilitation Support for the Chicago Area Waterway System Advisory Comrr	\$75,000
	72	Economic Development and Marketing Efforts	\$100,000
		Subtotal	\$465,910
GLRI Total			\$23,075,000

* The FY 2017 proposed funding was generally determined by assuming flat funding from the FY 2016 enacted budget. Highlighted cells indicate new or amended projects that have received funding in August 2017.

FY 2017 Agency Project Funding**

	#	Title	FY 2017 (\$)
USACE	1	Great Lakes Mississippi River Interbasin Study (GLMRIS) - Brandon Road	\$2,300,000
	2	Lab Experimentation and Modeling to Quantify Response to CO2 in a Flowing Environment	\$0
	3	Operation and Maintenance of Barriers	\$11,800,000
	4	Barrier I Constuction	\$0
	5	Telemetry - Barrier Efficacy Evaluation	\$200,000
	7	Monitoring and Response Team Support	\$0
	39	Ohio-Erie Canal Pathway Closure Assessment	\$0
	44	Field Testing of Water Jets to Mitigate Barge Entrainment of Fish and Floating Species	\$0
	45	Field Deployment of Barriers at Brandon Road Lock	\$0
	46	Asian Carp Swim Speed Study	\$0
	47	H & H Support for Eagle Marsh II	\$0
	65	Electric Field-Based Aquatic Nuisance Species Dispersal Barrier: Development and Implementation of an Alternating Current Electric Dispersal Barrier	\$0
	68	Electric Dispersal Barrier Electrode Replacement	\$0
	73	GLMRIS Program Management	\$300,000
	Subtotal	\$14,600,000	

USFWS	6	Great Lakes Asian Carp Monitoring Program	\$1,150,000
	7	Monitoring and Response Team Support	\$1,015,000
	8	Barge Entrainment and Interaction Study	\$300,000
	9	Hydro-Acoustic Assessment of Lock Mediated Fish Passage in the Upper Illinois River	\$0
	11	Program Capacity for eDNA Sampling	\$1,100,000
	12	Fisheries Capacity for eDNA Processing and Technology Refinement	\$1,300,000
	14	Asian Carp Strategic Communications Plan and Website Operation and Maintenance	\$100,000
	16	Registration of Microparticle Technologies	\$0
	17	Registration of Carbon Dioxide Technologies	\$0
	43	Program Support for Asian Carp Activities	\$75,000
	48	Black Carp Genetic Analysis	\$100,000
	49	Analysis of Grass Carp in the CAWS	\$30,000
	50	Black Carp Assessment: CAWS and UMRB	\$0
	51	Mass Removal and Monitoring of Juvenile Asian Carp	\$50,000
	52	Barrier Defense Using Novel Gear	\$35,000
	66	Predictive Model for Identifying Probability/Risk of Barges Entraining Asian Carps	\$0
	67	Genomic Mapping of Bighead and Grass Carp to Aid in Genetic Surveillance and Potential Genetic Control Efforts	\$45,000
	74	Field Deployment of Underwater Sound to Deter Asian Carp	\$300,000
75	Advancing eDNA Sampling and Other Genetic Tools for Invasive Black Carp	\$300,000	
	Subtotal	\$5,900,000	

FY 2017 Agency Project Funding**

	#	Title	FY 2017 (\$)
USGS	16	Registration of Microparticle Technologies	\$150,000
	17	Registration of Carbon Dioxide Technologies	\$50,000
	18	Development of Grass Carp Control Technologies	\$425,000
	19	Assessment of Hydraulic and Water-Quality Influences on Waterways to Develop Control Options	\$500,000
	20	Characterization of Brandon Road Lock for Barrier Implementation	\$0
	21	Use of Seismic Technology to Divert and Eradicate Asian Carp	\$20,000
	22	Field Deployment of Carbon Dioxide Barrier to Deter Asian Carp	\$310,000
	23	Developing Targeted (Microparticle and Piscicide) Control Systems	\$630,000
	25	Use of Acoustic Technology to Determine Behavior	\$150,000
	26	Improving Molecular Techniques for Monitoring, Biomass Estimation, and Correlation with Live Fish	\$800,000
	27	Integrated Pest Management Program	\$1,850,000
	45	Field Deployment of Barriers at Brandon Road Lock	\$0
	53	Use of Complex Sound to Alter Behavior of Asian Carp	\$183,000
	54	Development of Chemical Methods for Control of Aquatic Invasive Species during Lock Operations	\$70,000
	55	Communication and Demonstration of New Technologies for Control and Monitoring	\$20,000
56	Black Carp Control, Bait, and Attractant Use	\$70,000	
		Subtotal	\$5,228,000
USFWS-IL DNR	30	Enhanced Monitoring Above and Below Electric Barriers	\$0
	31	Illinois River Stock Assessment/Management Alternatives	\$0
	32	Contract Fishing for Asian Carp Detection and Removal	\$0
	35	Use of Improved Gear and Novel Designs at Brandon Road	\$0
	37	Community Action Initiatives to Increase Awareness, Surveillance, and Enforcement of Unlawful Live Asian Carp	\$0
	64	Black Carp Control	\$0
		Subtotal	\$0
ODNR	38	Killbuck Creek Pathway Closure Assessment	\$0
	39	Ohio-Erie Canal Pathway Closure Assessment	\$0
	59	Development of Grass Carp Response Capabilities in Ohio	\$0
		Subtotal	\$0
USCG	40	Manage Waterway Traffic in Support of Asian Carp Control Activities	\$73,000
	41	Brandon Road Lock and Dam Risk Assessment	\$2,000
	42	Electric Barrier Construction and Operation Risk Assessment	\$2,000
		Subtotal	\$77,000
NOAA	61	Food Web Modeling to Support Risk Assessment of Asian Carp in the Great Lakes	\$179,905
		Subtotal	\$179,905
MIDNR	60	Grass Carp Eradication in Western Lake Erie	\$0
		Subtotal	\$0

FY 2017 Agency Project Funding**

	#	Title	FY 2017 (\$)
NPS	71	Develop and Implement Education Materials and Lesson Plans in Coordination with Teachers to Further the Asian Carp Response in the Midwest	\$0
	Subtotal		\$0
USEPA	43	Program Support for Asian Carp Activities	\$0
	69	Facilitation Support for the Chicago Area Waterway System Advisory Committee	\$0
	72	Economic Development and Marketing Efforts	\$0
Subtotal		\$0	
Base Funding Total			\$25,984,905

** The FY 2017 proposed funding was generally determined by assuming flat funding from the FY 2016 enacted budget. Highlighted cells indicate new or amended projects that have received funding in August 2017.

FY 2017 Funding Summary

USACE GLRI Total	\$7,462,500
USACE Agency Total	\$14,600,000
USEPA GLRI Total	\$465,910
USEPA Agency Total	\$0
USCG GLRI Total	\$400,000
USCG Agency Total	\$77,000
USFWS GLRI Total	\$4,120,000
USFWS Agency Total	\$5,900,000
USGS GLRI Total	\$5,492,000
USGS Agency Total	\$5,228,000
USFWS - ILDNR GLRI Total	\$4,150,000
USFWS - ILDNR Agency Total	\$0
USFWS - ODNR GLRI Total	\$600,000
USFWS - ODNR Agency Total	\$0
USFWS - MIDNR GLRI Total	\$150,000
USFWS - MIDNR Agency Total	\$0
NOAA GLRI Total	\$159,590
NOAA Agency Total	\$179,905
NPS GLRI Total	\$75,000
NPS Agency Total	\$0
GLRI Total	\$23,075,000
Agency Funding Total	\$25,984,905