



Bighead carp



Silver carp



Grass carp



Black carp

USGS Science and Technology Help Managers Battle Invading Asian Carp

The USGS delivers high-quality data, technologies, and decision-support tools to help managers reduce existing populations and control the spread of Asian carp in the Nation's waterways.



Bighead carp

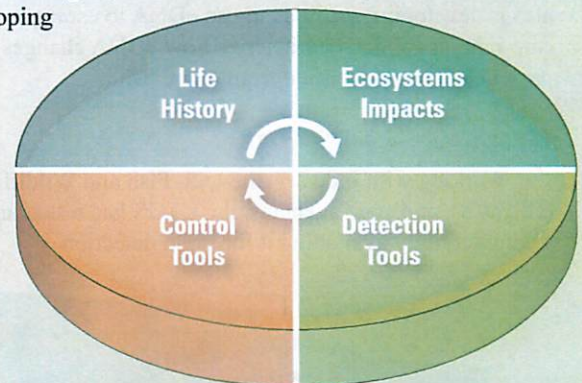
What are Asian Carp?

The term "Asian carp" is used here to refer to four species of fish introduced into the United States in the 1960s and 1970s. Asian carp now have reproducing populations in waters of the United States. These species have similar life histories but differ in diet and distribution. Bighead carp and silver carp are filter feeders that remove plankton from the water and are established throughout much of the Mississippi River Basin. Grass carp specialize on eating submerged aquatic plants and are widely distributed in the United States, with growing numbers of reproducing populations, including in the Lake Erie watershed. Black carp consume freshwater mussels, snails, and other mollusks and have a limited but expanding range in the Mississippi River.

The U.S. Geological Survey (USGS) conducts Asian carp research focused on early detection, risk assessment, and development of control tools and strategies. The goals are to prevent the establishment of invasive Asian carp in the Great Lakes and to reduce their impacts in the Ohio River and Mississippi River Basins and elsewhere. Managers can use the information, tools, and strategies for early detection of Asian carp and to control them when their presence is first evident. New detection and control tools are designed to accommodate expansion to other invasive species and application in geographically diverse areas.

This USGS focus complements goals of the Great Lakes Restoration Initiative (GLRI), a multi-agency collaboration started in 2010 to protect and restore the Great Lakes. As a member of the Asian Carp Regional Coordinating Committee, which guides Asian carp efforts, the USGS works closely with Federal and State agencies, Canada, and others to address high-priority Asian carp issues and provide science to inform management decisions.

The USGS has gained extensive knowledge of Asian carp biology and life history over the past 30 years. That knowledge guides the design, development, and application of control strategies, and is essential for developing approaches in line with modern principles and practices of integrated pest management (IPM). IPM is a process used to solve pest problems while minimizing risks to people and the environment.



Use of an integrated pest management approach helps managers focus monitoring and control efforts. These multiple areas of research are interrelated.

Early Detection

Early detection is a vital part of managing any invasive species. Detection of Asian carp is difficult because they avoid nets and other traditional capture gear, so they are hard to catch especially when populations are small. The USGS has contributed to the development and improvement of new genetic approaches to detect Asian carp at low abundances and identify initial invasions.



Samples containing environmental DNA are processed in a laboratory.

Environmental DNA

Improvements in the technology to detect environmental DNA (eDNA) offer the potential to provide managers a “genetic toolbox” for detection and characterization of Asian carp occurrence. This technology involves detection of DNA in an environmental sample, such as lake or river water. USGS research has led to refinements to past methods to improve detection sensitivity, increase cost-effectiveness, and decrease time between sampling and results. Current research efforts are focused on evaluating the application of eDNA detection as a tool to detect fish movement, habitat use, and spawning, and to evaluate the effectiveness of management actions. The USGS also is developing methods to use eDNA to estimate Asian carp biomass and to characterize how eDNA changes with the passage of time once shed from a live fish.

Portable eDNA Detection Device

Working with industry, the U.S. Fish and Wildlife Service (USFWS), and state agencies, the USGS has tested and validated a commercially available kit for rapid detection

of Asian carp using eDNA. The portable kit reduces the time between sample collection and results from days to less than 1 hour for time-critical samples. Field testing indicates that law-enforcement officers without any prior experience can use the kit to detect the presence of a single, minnow-sized silver carp commingled with more than 10,000 fathead minnows in a large fish tank. Additional testing and accompanying directions and protocols for sample collection are being developed. Training and equipping law-enforcement officers with detection kits available through the GLRI is planned.

Risk Assessment

Scientists do risk assessments to estimate the likelihood a species may invade, spread, or cause economic or ecological damage; to identify ecosystems or habitats most likely to be invaded; and to estimate other risks associated with species’ invasions. Risk assessments are part of the IPM process and help managers focus monitoring and control efforts. The USGS has worked with the Government of Canada on a completed international bighead carp and silver carp risk assessment and is part of a partnership developing assessments for grass carp and black carp. The USGS also strives to inform and support decision-makers by producing easy-to-use decision tools based on risk-assessment results.



Law enforcement processing eDNA samples.

Identification of Potential Spawning Sites

Understanding when Asian carp might be able to reproduce would inform monitoring and control efforts. Because not all habitats are suitable for reproduction, the USGS developed a computer model called Fluvial Egg Drift Simulator (FluEgg) to predict where river conditions would allow bighead, silver, and grass carp eggs and larval fish to survive until they find nursery habitat (fig. 1). FluEgg also can be used to assess risk of establishment of new spawning populations and to evaluate the effectiveness of control measures. It is applicable in areas where Asian carp are present and areas that have not yet been invaded. Identifying potential spawning areas may also provide opportunities for managers to disrupt spawning.

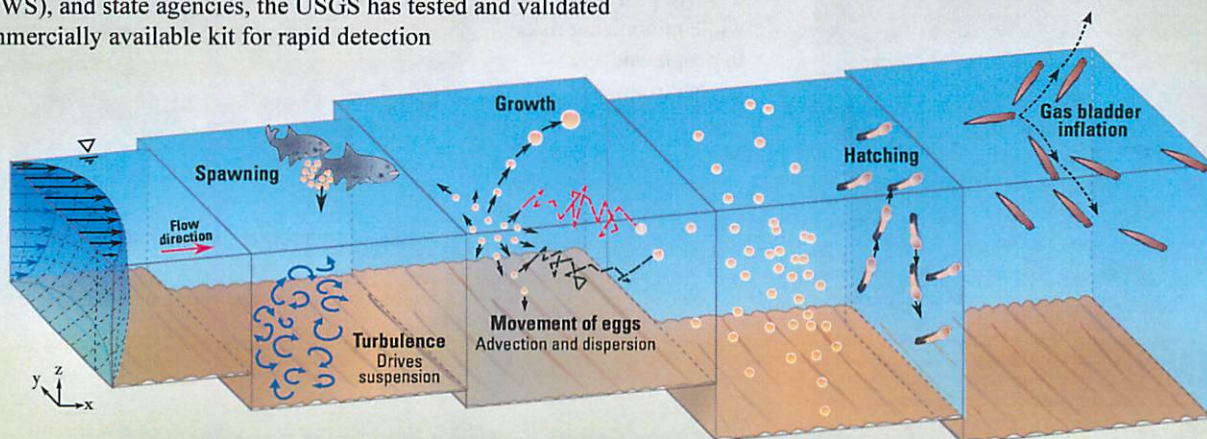


Figure 1. Conceptual schematic showing the Fluvial Egg Drift Simulator model and processes. (From Murphy and others, 2016.)

Assessment of Food Availability in the Great Lakes

Understanding the potential impact of Asian carp in areas not yet invaded requires determining if adequate food resources are available. Using satellite imagery, USGS scientists have determined that there is enough food available for bighead carp and silver carp to survive if they reached Lake Erie. Green algae and blue-green algae on the surface of the lake are a preferred food source for these fish. The water temperatures and algal concentrations detected in Lake Erie from 2002 to 2011 show that bighead carp and silver carp could live and grow in this environment. If bighead carp and silver carp were to populate Lake Erie, they could damage native fish populations and have negative effects on the economy of the Great Lakes Region. Scientists also have begun to inventory and map aquatic vegetation in Lake Erie to better understand availability of food for grass carp.

Integrated Containment and Control

USGS scientists continue to develop and test containment and control tools and technologies to enhance the ability of agencies to manage Asian carp to minimize their influence and spread. The USGS also is investigating options for combined implementation of tools in an IPM context. A variety of control options, including hot water, ozone, and those mentioned below, have or are being explored, sometimes in creative combinations to address Asian carp issues.

Preventing Movement toward the Great Lakes

In collaboration with the U.S. Army Corps of Engineers (USACE), the USGS continues to collect hydraulic and water-quality data and conduct analyses to answer engineering questions and inform modeling efforts at Brandon Road Lock and Dam (BRLD) and other locations in the Illinois River and the Chicago Area Waterway System. Continuous flow and water-quality data contribute to designing Asian carp controls that are effective even when storms, lock operations, and other factors change water flow. The USGS and the USFWS also have conducted experiments in the Illinois Waterway to understand the potential for young Asian carp to move into areas not yet invaded, including beyond electric dispersal barriers. The USGS has measured and analyzed the hydrodynamics around the barges and provided the information to managers that are working on mitigation strategies.

Carbon Dioxide

The results of laboratory studies and other research in experimental ponds suggest that silver carp and bighead carp avoid areas with elevated concentrations of carbon dioxide gas

(CO₂). This has led the USGS to explore the use of elevated CO₂ to deter the further spread of Asian carp in certain areas, such as above locks and dams. For example, the USGS is evaluating the behavior of Asian carp in CO₂ gradients in the field and testing methods to deliver CO₂. Research results show elevated CO₂ can be an effective deterrent for bighead carp and silver carp that could be integrated with multiple deterrents and barriers (for example, electric, sound, and CO₂) to provide control and redundancy.

Microparticles

The USGS is developing a targeted toxicant-delivery system in the form of a multilayered microparticle that is sized in the feeding range of bighead carp and silver carp but smaller than what most native fish feed on. The initial chemical incorporated into microparticles is Antimycin A, a U.S. Environmental Protection Agency (EPA)-registered fish toxicant, but the formulation of the particle can be modified to incorporate other potential fish-control chemicals. In laboratory studies, Asian carp consumed Antimycin A laden microparticles and died, but bluegill and largemouth bass did not. Initial studies to test Antimycin A laden microparticles in experimental ponds with algal attractants showed that microparticles killed a number of the silver carp and bighead carp in the pond without killing largemouth bass. Options for field experiments are now being explored. USGS researchers are adapting use of microparticles for other toxicants, bioactive compounds, and to target grass carp and other invasive species.



USGS scientists measuring flow velocity in a lock channel.

Algal Attractants

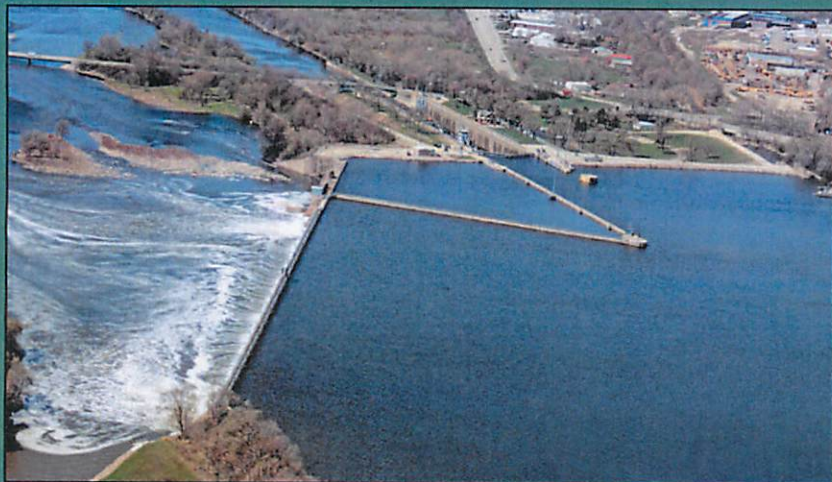
USGS scientists have discovered that Asian carp are strongly attracted to certain mixtures of algae and have been testing methods for using the attractants as lures to facilitate fish capture and removal. In expanded studies, algal compounds favored by Asian carp are being applied as an attractant through “feeding stations” deployed in conjunction with nets and traps. The attractants help draw Asian carp toward nets, traps, and other capture gear. The effectiveness of the gear for harvesting fish is then evaluated. Other studies involve the pairing of underwater sound with algal attractants to see how that combination affects Asian carp responsiveness to feeding stations, and testing the use of feeding stations for enhancing fish attraction during microparticle application.

Underwater Sound

The USGS is testing the use of underwater sounds to deter further spread of Asian carp. Working with the University of Minnesota, the USGS determined that bighead carp and silver carp react strongly to the broadband outboard-motor sound. Bighead carp and silver carp swam away from the recorded sound of a boat motor as many as 37 times in succession, whereas many

Creating Barriers — Stopping Asian Carp at Brandon Road Lock and Dam

In the Great Lakes Mississippi River Interbasin Study, the U.S. Army Corps of Engineers (USACE) is assessing the viability of establishing a single point to control the one-way, upstream transfer of Asian carp and other aquatic nuisance species from the Mississippi River Basin into the Great Lakes Basin near the Brandon Road Lock and Dam (BRLD) located in Joliet, Illinois. The USGS is providing critical hydraulic data and analyses to help the USACE understand water flow and quality around the BRLD and inform barrier decisions, and to provide information for testing control tools.



Brandon Road Lock and Dam has been identified by the USACE as a downstream control point of the Chicago Area Waterway System for Asian carp and a number of other aquatic nuisance species. The topographic and geographic positioning of the site allows it to serve as a single point of passage for species able to move upstream toward the Great Lakes. (Photograph by U.S. Army Corps of Engineers, April 22, 2014.)

them where they now occur, including the Ohio River and Mississippi River Basins. Contributions by the USGS to inform integrated pest management are particularly important, especially the objective evaluation of tools for control. The USGS will continue this important research, coupled with education, synthesis, publication, and other forms of knowledge transfer that inform management solutions.

Reference Cited

Murphy, E.A., Garcia, Tatiana, Jackson, P.R., and Duncker, J.J., 2016, Simulation of hypothetical Asian carp egg and larvae development and transport in the Lockport, Brandon Road, Dresden Island, and Marseilles Pools of the Illinois Waterway by use of the fluvial egg drift simulator (FluEgg) model: U.S. Geological Survey Open-File Report 2016-1011, 19 p., <http://dx.doi.org/10.3133/ofr20161011>.

The USGS, in collaboration with the Great Lakes Restoration Initiative and Asian Carp Regional Coordinating Committee, provides science and technology to control the spread of Asian carp.



native fishes had little to no response. This suggests that sound may have some specificity for bighead carp and silver carp, and deter them from entering an area while allowing native fishes to move freely. Studies also are underway to evaluate the use of sound to move fish and improve capture and removal.

Making New Detection and Control Tools Available for Use

As new tools are developed, managers need information about how the tools work, the information they provide, and how to use them. The USGS works with resource managers to better understand the Asian carp issues that managers want to address. The USGS also leads training sessions and workshops to meet managers' needs and to introduce new tools, technologies, and scientific findings.

Compliance with environmental regulations is a major management consideration when applying chemical or biological control tools in any water body. To address environmental regulations, the USGS is collaborating with the USFWS and the EPA to develop the information needed to register chemical controls like CO₂ and Antimycin A laden microparticles with the EPA and State regulatory agencies. The USGS and USFWS also are working to identify species for testing to assess potential effects of chemical or biological controls on threatened and endangered species.

The Future

The negative effects of invasive Asian carp in North America already are far reaching and have real potential to expand and intensify. A wide variety of organizations are working to keep these invasive fish out of the Great Lakes and other aquatic ecosystems and control

Authors:

Cynthia S. Kolar and Sandra S. Morrison

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For more information:

Ecosystems Mission Area
<http://www.usgs.gov/ecosystems/>
<http://www.usgs.gov/ask/>
1-888-ASK-USGS (1-888-275-8747)

USGS Asian carp science — https://www2.usgs.gov/ecosystems/invasive_species/midwest.html —
<http://cida.usgs.gov/glri/index.jsp#/Home/AsianCarp>

Great Lakes Restoration Initiative —
<http://greatlakesrestoration.us>

Asian Carp Regional Coordinating Committee —
<http://www.asiancarp.us>

National Asian Carp Plan —
http://anstaskforce.gov/Documents/Carps_Management_Plan.pdf

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Background

- Asian carp are a non-native, invasive species of fish in North America. Types of Asian carp in the Tennessee River watershed include: Grass, Black, Bighead and Silver carp.
- Grass carp are used for managing aquatic vegetation. They are not a concern because they are sterile and cannot reproduce.
- Bighead carp and Silver carp are of the most concern. The invasion of these carp threatens multiple agencies, sport fisheries, ecosystems, recreation and economic development.
- They are believed to be migrating upstream and passing through locks but there is uncertain data regarding their abundance, their movement and their reproduction rates.
- Asian Silver carp are very prolific and can quickly become over-abundant, which can lead to adverse impacts to native fish populations in the lakes and rivers that they infest because they out-compete other fish for food and space.
- The Tennessee Wildlife Resources Agency is the lead agency charged with spearheading the effort against Asian Silver carp. TVA supports TWRA in its efforts.

Who is responsible for what?

- The states (KY, MS, AL, TN) are responsible for fisheries management.
- The USFWS obtains funding from Congress and facilitates programs.
- The USACE operates the locks in the Tennessee and Cumberland Rivers.
- TVA manages the water and operates the dams in the Tennessee River.

Collaborative Approach to Controlling Asian Silver Carp

- The challenge of controlling Asian Silver carp in the Tennessee River system requires that TVA and our partners remain focused, effective, and innovative.
- TVA recognizes the magnitude of the Asian Silver carp threat and is committed to continuing our efforts by collaborating and leveraging resources through partnerships, using the best available science to inform and adapt management approaches, and employing innovative technologies aimed at stopping the spread of these fish.

Mississippi Interstate Cooperative Resource Association (MICRA)

- MICRA is a partnership of 28 state agencies with fisheries management jurisdiction in the Mississippi River Basin.
 - Federal agencies participate in the MICRA partnership.
 - TVA is a member of MICRA.
- States have recommended that Tennessee Wildlife Resources Agency (TWRA) work through MICRA for multi-state planning and coordination. TVA is supporting TWRA in that plan.
- MICRA objectives include surveillance of Asian Silver carp movement, reproduction, life span, etc. with tagging and tracking. Universities in the region are helping in that effort.
- Since carp tend to form tight schools (groups), one way of tracking silver carp is by tagging individual fish so the school can be tracked.
 - This is known as the “Judas fish” technique.
 - The fish can then be effectively netted.

- Educational and outreach efforts are also underway to encourage anglers to catch and eat Silver carp.
- Responsibilities of each entity of MICRA:
 - States (KY, MS, AL, TN): Fisheries management
 - U.S. Fish & Wildlife Services: Obtains funding from Congress and facilitates program
 - U.S. Army Corps of Engineers (USACE): Operates the locks in the Tennessee and Cumberland Rivers
 - TVA: Manages the water and operates the dams on the Tennessee River

Actions

- TVA has been tracking the spread and establishment of Silver carp in the Tennessee Valley and will continue our efforts and support of the national strategies for Silver carp.
- Partnership/Annual Projects:
 - Conducts annual valley-wide fish and benthic macroinvertebrate assessments throughout the Valley to determine effects of Silver carp on aquatic communities.
 - Partnered with Tennessee Wildlife Resources Agency (TWRA) and BASS to serve over 100 pounds of silver carp at the 2019 Bassmaster Classic in Knoxville, TN.
 - Partnered with the Tennessee Aquarium for three events to raise awareness of Silver carp in the Tennessee River.
 - Provided funding to the Kentucky Department of Fish and Wildlife Resources to purchase an ice machine for the commercial fishery.
 - Provided funding to TWRA to support the analysis of populations and tracking the migration of Silver carp up the Tennessee River, which helped them secure a larger grant to support the effort.
- Studies/Evaluations:
 - Evaluating barrier technologies to be incorporated into the new Kentucky Lock lower approach wall with the USACE and TWRA.
 - Several technologies are being tested on the Mississippi and Cumberland Rivers to stop the migration of carp into the Great Lakes. The U.S. Geological Survey (USGS) has secured funding for the placement and evaluation of barriers in the Tennessee and Cumberland Rivers and is considering several TVA locks and dams as candidate sites for the installation. TVA is evaluating NEPA review requirements for the proposed Tennessee River projects as a programmatic EA or EIS.
 - USGS and the Ohio River Asian Carp sub-basin team of State and Federal partners are testing a method of carp capture at Kentucky Lake that has proven very effective in China to remove several tons of fish from embayments. Senator McConnell and Rep. Comer will be visiting the testing area on February 17.

Next Steps

- Continue collaborative and partnering efforts
- Evaluate a small-scale R&D barrier installation at one of our locks
- Move forward with environmental review and feasibility study to evaluate entire system
- Enhance communications about our efforts to stakeholders

Combating the Spread of Asian Carp in Southeastern Waters

Background

- Four species of Asian carp—bighead, black, grass and silver—have steadily expanded their range the last 50 years across the Mississippi River Basin. They were brought to Arkansas and Mississippi to control water quality in aquaculture ponds. Hurricanes and floods, though, allowed the carp to escape and, eventually, end up in the Mississippi River.
- Much of America's interior river system is now occupied by one or more Asian carp species; at least one type of carp exists in 45 states. They are now working their way up the Ohio, Cumberland, Tennessee, Arkansas, Red and White rivers.
- Asian carp are voraciously invasive and target the Southeast's rich biodiversity. They eat at-risk, threatened or endangered mussels and snails, as well as basic food sources like phytoplankton that sustain sport fish like crappie and largemouth bass.
- Billion-dollar tourism and sport-fishing industries, vital to local economies, are also under attack.
- Kentucky is at the forefront of the battle against carp.

Money and management

- A national anti-carp framework has been developed in collaboration with more than 70 federal, state, non-governmental, and industry partners. It was approved by the Aquatic Nuisance Species Task Force in 2007 and serves as the overarching plan for managing Asian carp. In addition, each of the six sub-basins with carp problems has set their own priorities.
- The U.S. Fish and Wildlife Service (Service) is leading the multiagency carp-deterrent efforts. Congress appropriated \$25 million to the Service in fiscal year 2020, a \$14 million increase that will allow the Service to fund anti-carp projects in all six sub-basins.
- In the South, the Service has been funding Kentucky and Tennessee removal and monitoring efforts since 2016 in the Ohio, Tennessee and Cumberland Rivers and tributaries. The Service has added Mississippi and Alabama the last two years.

Fighting Asian carp in Kentucky

- The Modified-Unified Method is the latest carp-fighting tool deployed in Kentucky. The removal system will corral carp on Kentucky Lake with a series of nets and boats utilizing underwater speakers and electrofishing gear. The project should last through February 2020. The Service is providing technical assistance, equipment, and personnel to implement this removal method at Kentucky Lake.
- A bio-acoustic fish fence, or BAFF, is also deployed at Kentucky's Lake Barkley lock and dam. The \$7 million, three-year field trial is designed to keep carp from entering the lock's chamber. It deploys customized sound signals, strobe lights and an air-bubble curtain to steer the fish away from the lock chamber. The BAFF, a collaboration between the Service, U.S. Army Corps of Engineers, U.S. Geological Survey, the Kentucky Department of Fish and Wildlife Resources and others, has the potential to deter the movement of invasive fish without impeding navigation.
- State biologists in Kentucky and Tennessee use Service money to track carp movements via acoustic transmitters placed throughout the Ohio and Tennessee river basins. They also use eDNA to determine the leading edge of the carp invasion.
- Commercial fishers, contracted by the Kentucky Department of Fish and Wildlife Resources, have harvested more than four million pounds of Asian carp from Kentucky lakes, Barkley in particular.

For more information:

Dan Chapman, Public Affairs Specialist
U.S. Fish and Wildlife Service
Dan_Chapman@fws.gov
404/679-4028
www.fws.gov/southeast/faq/asian-carp-in-southeastern-waters/