

Science *and* Innovation *for* Battling Invasive Carp

The U.S. Geological Survey (USGS) delivers high-quality data, technologies, and decision-support tools to help managers reduce existing populations and control the spread of invasive carp.

What are Invasive Carp?

Invasive species are non-native organisms whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health. Invasive carp include bighead carp (*Hypophthalmichthys nobilis*), silver carp (*H. molitrix*), grass carp (*Ctenopharyngodon idella*), and black carp (*Mylopharyngodon piceus*). These species were imported to the United States from China to control aquatic vegetation (grass carp in 1963; Guillory and Gasaway, 1978), algae (bighead carp in 1973), and the yellow grub (*Clinostomum marginatum*) fish parasite (black carp in the 1970s; Nico and others, 2005). The silver carp introduction date is not known. All four carp species escaped containment from the 1970s to 1990s. They are now established in the Mississippi River Basin and several of its sub-basins, including the Illinois, Ohio, Missouri, and the Tennessee/Cumberland Basins (not shown; Chapman and others, 2021).

Bighead and silver carp have negatively affected native fish populations throughout the Illinois River (Irons and others, 2007). If they were to enter the Great Lakes, they would threaten its \$7 billion per year fishery. Additionally, high-density populations of bighead and silver carp in Kentucky Lake (not shown) threaten fisheries and recreational boating in Tennessee and Kentucky. Integrated management strategies could help to monitor, control, and contain populations of invasive carp from expanding.

Invasive carp include bighead carp, silver carp, grass carp, and black carp. Bighead and silver carp are sometimes referred to collectively as bigheaded carp because of their large heads.

Bighead Carp



Bighead carp are filter feeders that remove microscopic plants and animals called plankton from the water, making it unavailable for other fish. They compete with native paddlefish (*Polyodon spathula*) for food. They are established throughout much of the Mississippi River Basin.

Photograph by Ryan Hagerty, U.S. Fish and Wildlife Service.

Silver Carp



Because moving boats frighten the carp, silver carp often jump into boats, occasionally injuring boaters or damaging equipment. Sometimes schools of silver carp will jump simultaneously. They are established throughout much of the Mississippi River Basin.

Photograph by Sam Stukel, U.S. Fish and Wildlife Service.

Grass Carp



Grass carp have a specialized diet of submerged aquatic plants. Sterilized grass carp are frequently used to control nuisance aquatic vegetation in ponds and lakes. However, naturally reproducing populations can damage native vegetation, which can harm native fish communities. Naturally reproducing grass carp are found throughout the lower and middle Mississippi River, several of its subbasins, the upper Colorado River, and Lake Erie. Management agencies are actively reducing the Lake Erie population.

Photograph by Ryan Hagerty, U.S. Fish and Wildlife Service.

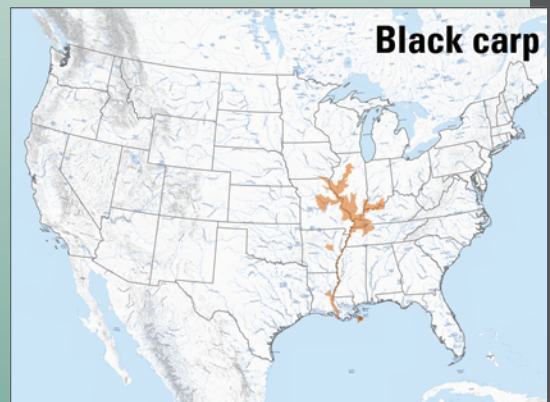
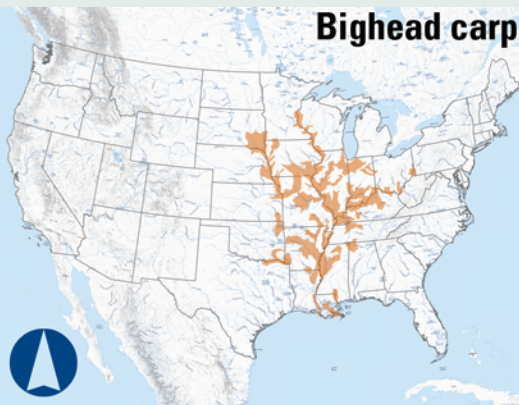
Black Carp



Black carp consume freshwater mussels, snails, other mollusks, and invertebrates. Their range is expanding and now includes the lower and middle Mississippi, Missouri, Ohio, and Illinois Rivers. Black carp are a threat to native and endangered freshwater mussels.

Photograph by Ryan Hagerty, U.S. Fish and Wildlife Service.

Maps from the U.S. Geological Survey Nonindigenous Aquatic Species Database (<https://nas.er.usgs.gov>) of established ranges of bighead, black, grass, and silver carps.



The U.S. Geological Survey provides natural-resource managers with scientific information, risk assessment, and tools that can help to improve surveillance, prevention, and control strategies for managing invasive carp.

The Need for Intervention

High-density populations of bighead and silver carp threaten boaters, anglers, native fish populations, and economies throughout the lower and middle reaches of the Mississippi, Missouri, and Ohio River Basins (not shown). These carp species have expanded throughout the entire Illinois River where they risk invading the Great Lakes through the Chicago Area Waterway System, thus threatening its \$7 billion per year fishery. Expansion of bighead and silver carp into the Tennessee and Cumberland Rivers also threatens fisheries and boating. Reproducing populations of grass carp in Lake Erie risk damaging aquatic vegetation, which could cause a cascade of negative effects in fisheries, including an increased risk of wave erosion and harmful algal blooms that pollute water supplies. Black carp, which have expanded throughout the lower Mississippi River and into the Missouri, Ohio, and Illinois Rivers, threaten to destroy native and endangered mussel populations.

The immediate need is to stop expansion of all invasive carp species into southeastern rivers of the United States and the Great Lakes and to reduce or eradicate grass carp in the Great Lakes.

USGS Science in Action

The USGS conducts leading-edge research and develops tools and techniques to help managers reduce populations of invasive carp within an integrated pest management (IPM) framework. IPM promotes integrating biological, chemical, cultural, and physical tools to combat invasive species.

Detection/Monitoring

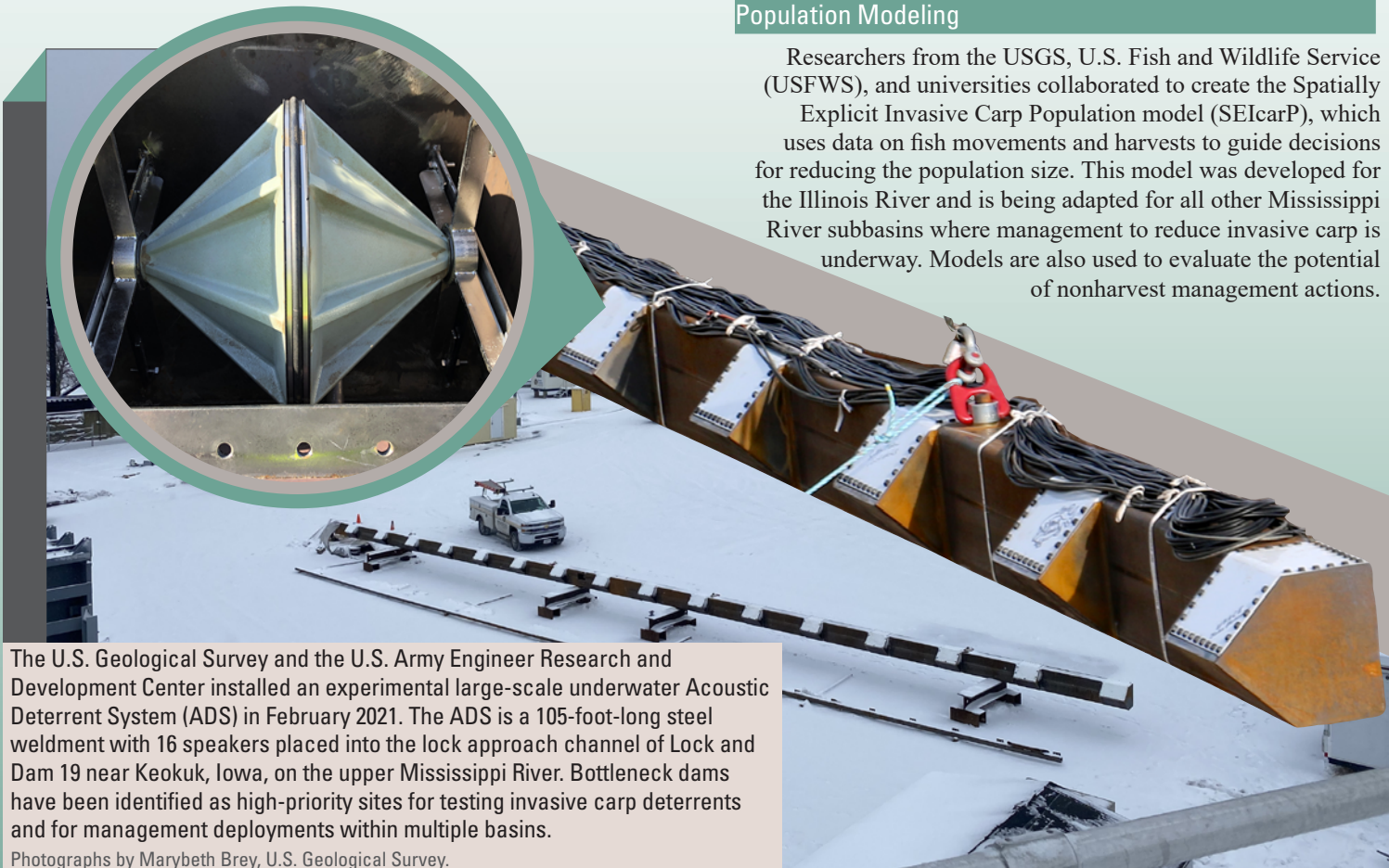
USGS researchers are leading efforts to use genetic data such as environmental deoxyribonucleic acid (eDNA) to detect the presence and increasing numbers of invasive carp in spawning areas. The USGS also works with State and university partners to refine the use of sound navigation and ranging (sonar) to detect and estimate numbers of invasive carp before and after removal (see enhanced mass removal below). The USGS [Nonindigenous Aquatic Species database](#) is the most comprehensive repository for records of aquatic invasive species in the United States, which allows managers, researchers, and the public to monitor the invasion status of invasive carp.

Structured Decision Making

USGS researchers led and participated in several structured decision making (SDM; Post van der Burg and others, 2021) processes that helped identify information gaps and management needs and guided actions to achieve those needs. Successful SDMs in the Great Lakes for grass carp and in the Tennessee and Cumberland Rivers for silver carp have led to development and implementation of management plans tailored to local needs.

Population Modeling

Researchers from the USGS, U.S. Fish and Wildlife Service (USFWS), and universities collaborated to create the Spatially Explicit Invasive Carp Population model (SEIcarP), which uses data on fish movements and harvests to guide decisions for reducing the population size. This model was developed for the Illinois River and is being adapted for all other Mississippi River subbasins where management to reduce invasive carp is underway. Models are also used to evaluate the potential of nonharvest management actions.



The U.S. Geological Survey and the U.S. Army Engineer Research and Development Center installed an experimental large-scale underwater Acoustic Deterrent System (ADS) in February 2021. The ADS is a 105-foot-long steel weldment with 16 speakers placed into the lock approach channel of Lock and Dam 19 near Keokuk, Iowa, on the upper Mississippi River. Bottleneck dams have been identified as high-priority sites for testing invasive carp deterrents and for management deployments within multiple basins.

Photographs by Marybeth Brey, U.S. Geological Survey.

Egg Drift Modeling

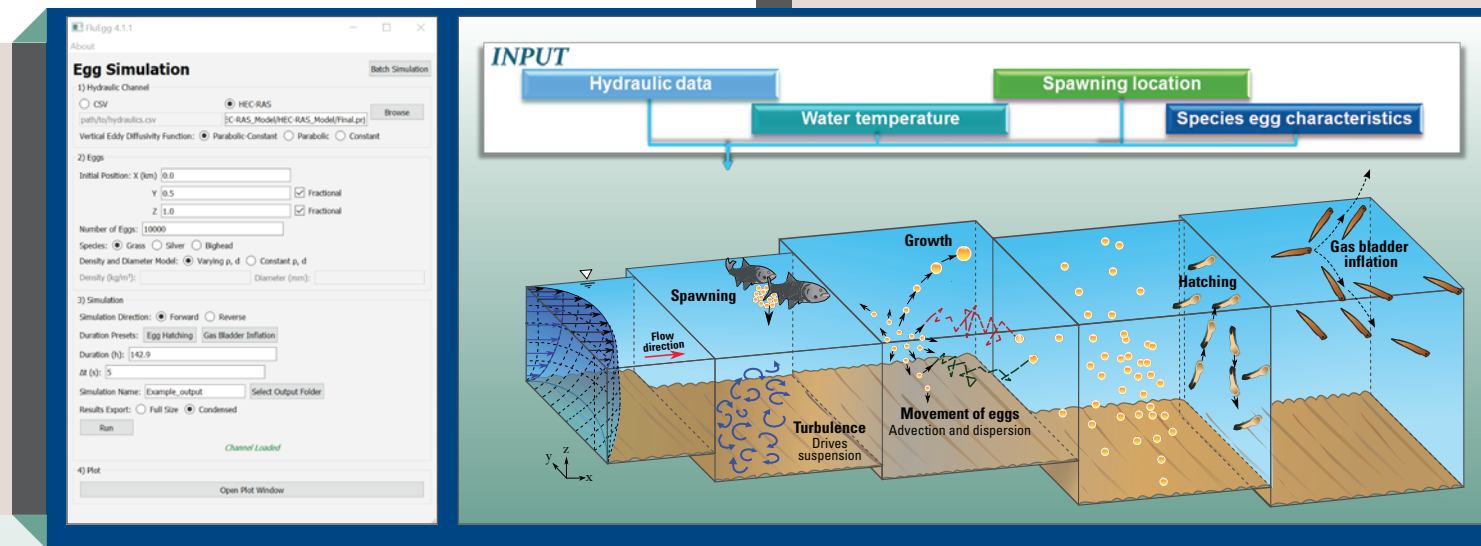
USGS researchers developed, implemented, and validated the Fluvial Egg Drift Simulator, a model to assess risks associated with invasive carp reproduction. This model has been used to identify and verify spawning areas for grass carp in Lake Erie tributaries and silver carp in the Illinois River. It can also be used to predict locations of invasive carp eggs and larvae to assess risk of successful reproduction and inform control efforts.

Deterrents

The USGS is a leader in developing and testing invasive carp deterrents. Taking advantage of the tendency for silver carp to avoid certain noises such as outboard motors, the USGS and university researchers identified sound frequencies and patterns

that repel silver and bighead carp and developed an ADS. A field test began in 2021 at Lock and Dam 19 on the Mississippi River near Keokuk, Iowa (not shown). The USGS is also working with USFWS and State partners to research the effectiveness of a bioacoustic fish fence, which uses injected air bubbles, light, and sound to repel fish. The USGS completed laboratory, pond, and large-scale field tests of infused carbon dioxide captured as a byproduct of ethanol production as an avoidance deterrent for bighead, grass, and silver carp. Infused carbon dioxide does not add substantial amounts of carbon dioxide to the atmosphere. The USGS led efforts to register Carbon Dioxide-Carp as a new aquatic pesticide for control of invasive carp.

Fluvial Egg Drift Simulator interface and conceptual model.
Images by the U.S. Geological Survey.



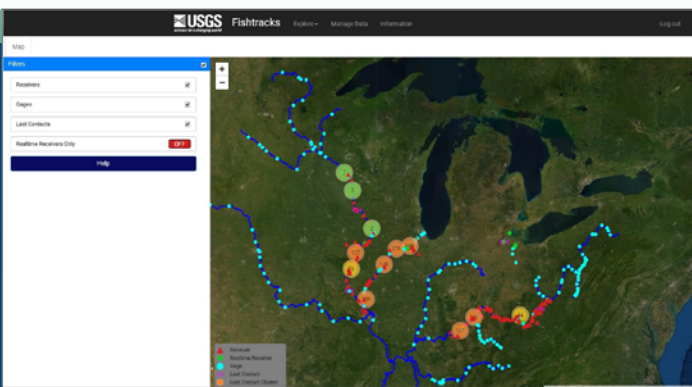
The Acoustic Deterrent System installed near Keokuk, Iowa, February 2021.
Photograph by Mark Cornish, U.S. Army Corps of Engineers.

Baits and Attractants

USGS scientists are leading development of food-based attractants for bighead, grass, and silver carp to increase capture rates. Researchers are also examining whether sounds produced by invasive carp as they feed might attract other invasive carp. Scientists did successful field tests on algae attractants in Illinois River backwaters from 2014 to 2016. Attractants for grass carp were field tested in Michigan and Ohio waters of Lake Erie in 2021.

Pesticides

USGS researchers are developing pesticides that target bighead and silver carp by mimicking the size of food particles these species prefer. Laboratory tests have shown particles can be produced that induce high levels of mortality in bighead and silver carp while causing no or minimal harm to native fish. The USGS is working toward registration of these pesticides and methods to transition to full-scale field tests and implementation.



Map interface of the FishTracks Telemetry database and web application, showing the location of deployed acoustic telemetry receivers throughout the upper Mississippi River Basin to support the monitoring and removal of invasive carp.

Photograph by the U.S. Geological Survey.



Using a Van Dorn sampler to collect environmental deoxyribonucleic acid water samples during a lethal control carbon dioxide trial.

Photograph by the U.S. Geological Survey.

Enhanced Mass Removal

USGS scientists modified the Unified Method, a Chinese method for mass removal of silver and bighead carp, using sonar and underwater sound to more rapidly herd fish and accelerate their removal in North American waterways. This method has been used successfully in backwaters and embayments of the Illinois, Mississippi, Missouri, and Tennessee/Cumberland Rivers to instruct State resource agencies on techniques and remove hundreds of thousands of pounds of invasive carp.

Telemetry and Tracking Databases

The USGS developed and manages the FISHTRACK database, which houses information on invasive carp movements using acoustic, radio, and satellite telemetry. The database is used to track fish movements and identify areas where fish congregate to target harvest efforts; to develop, test, and implement barriers; and to improve and adapt the SEIcarP model to new systems. In the Great Lakes, acoustic telemetry is used to target grass carp removal efforts and to assess expansion.

Integrated Pest Management

The USGS works with the Department of the Interior and other partners to follow principles of IPM for managing invasive carp. Integrating multiple approaches increases the chances of success while minimizing the risk of negative ecological, economic, and cultural effects.



Silver (left) and bighead (right) carp collected in the Illinois River.

Photograph by the U.S. Geological Survey.

Control Technologies

The USGS has conducted research on several control technologies throughout the Mississippi River basin and its tributaries.

- Field trials in 2016–17 at Emiquon Preserve in Lewistown, Illinois, tested carbon dioxide and sound as deterrents for invasive carp.
- Scientists deployed temporary, experimental bigheaded carp sound deterrents twice in the Chicago Area Waterway System during U.S. Army Corps of Engineers (USACE) electric barrier maintenance.
- As part of the Great Lakes Mississippi River Interbasin Study, the USGS and USACE developed a model of how sound spreads at Brandon Road Lock and Dam on the Illinois River (in Joliet, Ill.) to plan for a speaker array.
- The USGS and USACE field tested newly developed sound signals using wild fish in the Wabash River, Indiana, in 2019.

- The USGS and partners tested the engineering and economic feasibility of injecting environmentally safe carbon dioxide into a navigational lock in 2019. The USGS and USFWS submitted the Section 3 Registration Packet to register carbon dioxide as a fish deterrent and pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. §136 et seq.). The U.S. Environmental Protection Agency (EPA) approved the registration in 2019.
- In 2020, the USGS began two long-term monitoring projects at Lock and Dam 19 on the Mississippi River (near Keokuk, Iowa) and at Barkley Dam on the Cumberland River (in Grand Rivers, Kentucky) to test the efficacy of the ADS and a bioacoustic fish fence.
- USGS and USFWS scientists are working with the EPA to register a species-specific, pesticide-laden microparticle control that resource managers could use to decrease existing populations of bigheaded carp. This control could potentially reduce upstream movement of bigheaded carp to areas of lower density while minimizing effects on native organisms.



Silver carp jumping.
Photograph by the
U.S. Geological Survey

U.S. Fish and Wildlife Service personnel net silver carp jumping in the Fox River.
Photograph by Ryan Hagerty, U.S. Fish and Wildlife Service.

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