

AQUATIC INVASIVE SPECIES

Bighead Carp in the Upper Midwest River: Competition with Native Filter-feeding Fishes and Potential Threats to the Great Lakes

Final Report

Bighead carp (*Hypophthalmichthys nobilis*) are a planktivorous fish native to rivers in China. They were brought to North America in the 1970s by fish farmers in Arkansas to reduce turbidity (phytoplankton and zooplankton "blooms") in aquaculture ponds. They escaped from these ponds during the floods of 1994, and are spreading throughout the Mississippi River basin, including the Illinois River. As they expand their range in the Illinois River, there is increasing concern that this fish will continue to spread upstream into the Great Lakes. This concern stems from the fact that the majority of fishes important to commercial and recreational fisheries in the Great Lakes depend on zooplankton during some portion of their life history. In light of the stress to the Great Lakes ecosystems from previous invasions by non-native species, bighead carp likely would have negative impacts on the fisheries of the Great Lakes and thus on the economies of coastal communities.

In order to predict the potential impacts of bighead carp in the Great Lakes, it is necessary to understand their dietary habits and the environmental factors that influence their establishment in new areas. This project will provide such information by 1) examining diets of bighead carp collected from the Mississippi and Illinois rivers, and 2) comparing current distributions of bighead carp with long term environmental data (e.g., water quality, aquatic vegetation, etc.) to determine what conditions favor their reproduction and persistence. This project will also test the potential effectiveness of the Chicago Waterways electronic dispersal barrier in restricting the spread of bighead carp, and identify minimum thresholds of the strength and width of an electric field required to prevent passage of this species. All of this information will allow Great Lakes resource managers to respond more effectively to the potential threat of bighead carp.

Major Goals and Objectives

Statement of Problem: Bighead carp (*Aristichthys nobilis*) are large, filter-feeding fish native to eastern Asia. Reproducing populations of bighead carp have become established in the Upper Mississippi River System and are spreading upstream in both the Mississippi and Illinois rivers. If this invasive movement remains unchecked, it is likely that bighead carp will enter the Great Lakes within the next few years. The introduction of bighead carp to the Great Lakes would pose serious threats to the ecology of these systems and to the economies of coastal communities that depend on Great Lakes resources. The objectives of this study are:

- To determine the extent of dietary overlap between bighead carp and native filter-feeding fishes in the Mississippi and Illinois river systems.
- To use data from the Long Term Resource Monitoring Program to examine whether specific environmental factors correlate with successful reproduction of bighead carp in the Upper Mississippi River System.
- To test the effectiveness of an electric barrier in restricting the spread of bighead carp.

Summary of Progress

Our work to date has focused on hiring appropriate personnel, collecting zooplankton and stomach content samples from the Mississippi and Illinois rivers, acquiring monitoring data from the USGS Long Term Resource Monitoring Program (LTRMP), and conducting initial barrier experiments. Schuyler Sampson was hired as a technician to collect fish and zooplankton samples. He will be entering the University of Illinois' Natural Resources and Environmental Sciences Department this spring to pursue a Master's Degree. Schuyler's thesis will focus on dietary overlap between bighead and silver carp (a second introduced Asian

carp, also a filter- feeder) and native filter feeding fishes. Ron Taylor was hired to coordinate the barrier experiments.

Zooplankton and fish samples were collected from nine backwater lakes in the Mississippi River, and eight backwater lakes in the Illinois River. All zooplankton samples have been processed. Although we have not completed analysis of these data, it is clear that zooplankton abundance and composition varied substantially among lakes, which will allow us to examine bighead carp diet under a variety of conditions. The total catch of filter feeding fishes from the nine backwater lakes in the Mississippi River was 85 bighead carp, 45 silver carp, 137 gizzard shad, 43 bigmouth buffalo, and 18 paddlefish. Total catch for Illinois River backwater lakes was 87 bighead carp, 1 silver carp, 143 gizzard shad, 79 bigmouth buffalo, and 5 paddlefish. Abundance of bighead carp varied substantially among backwater lakes, which will allow us to examine patterns of native fish diet as a function of Asian carp abundance.

All LTRMP fish and water quality data have been downloaded and converted to an access database. We will soon begin analyzing relationships between Asian carp spawning success and habitat measures.

To conduct our electric barrier experiments, we are using three large brood raceways at the Jake Wolf Memorial Fish Hatchery in Topeka, Illinois (Illinois Department of Natural Resources). The Jake Wolf Memorial Fish Hatchery is located near the Illinois River in an area where established populations of bighead carp currently exist. We are working closely with Smith - Root, Inc., a world leaders in the design and construction of fish barrier systems.

We conducted a number of preliminary experiments evaluating the effectiveness of electric barrier types in restricting the movement of bighead and silver carp using a modified Smith-Root (LR - 24) backpack electro - shocker. With this equipment we were able to create a very simple "two - electrode" low - level electric field fish barrier. Bighead and silver carp were highly sensitive to our low - level electric field. Qualitative visual observations of fish behavior indicated that these two species of Asian carp are capable of avoiding background field levels not detectable using a Smith - Root Inc. electric field probe. However, when frightened both bighead and silver carp were capable of crossing the electric barrier.

We have also conducted controlled experiments using two Smith - Root Inc. Fish Barrier Pulsators (Model BP - 1.5 POW) and have created an "eight electrode graduated field array". Using this array configuration, we are therefore better able to emulate active barrier conditions in the Chicago Sanitary and Shipping Canal at Romeoville, IL. The majority of the fish used in our experiments have remained some distance back from our active electric barrier array. We have concluded that both bighead and silver carp are capable of sensing and subsequently avoiding very low - level electric fields. Our findings indicated that our electric barriers were 96% effective in restricting the movement of bighead and silver carp. Successful repels in relation to the number of attempts to cross our electric barriers exceeded 99.5%. Although highly effective in restricting the movement of both bighead and silver carp, we observed that both bighead and silver carp are capable of crossing the electric barrier when frightened.

Accomplishment/Benefits

This project will allow us to assess potential impacts of bighead and silver carp on native fishes in the Mississippi and Illinois rivers, and methods to halt their spread to the Great Lakes. We may be able to suggest possible improvements to the design of the active electric barrier in the Chicago Sanitary and Shipping Canal. Pending results, we may also be able to provide insight regarding the creation of additional fish barriers (e.g. acoustic / bubble) specific to bighead and silver carp. Our research findings to date indicate that electric barriers may not be 100 percent effective in restricting the movement of both bighead and silver carp.

Keywords

Bighead Carp, Silver Carp, Filter-feeding Fishes, Dietary Overlap, Fish Barrier, Electric Field, Mississippi River, Illinois River, Great Lakes, Asian Carp, Zooplankton, Phytoplankton.

Narrative Report

Bighead carp were brought to the United States in the 1970's for use in aquaculture and subsequently escaped into the Mississippi River. During the 1990's, they established breeding populations in the Mississippi, Ohio, and Missouri rivers. Bighead carp typically consume zooplankton but are adaptable and will consume zooplankton, algae, and/or detritus depending on environmental conditions. Because all fishes typically feed on zooplankton in their larval and/or juvenile stages, bighead carp have the potential to adversely affect every species of fish in the Mississippi Basin and Great Lakes. Bighead carp are spreading upstream in both the Mississippi and Illinois rivers. If the upstream spread of bighead carp is not halted, they are likely to enter the Great Lakes within the next few years via the connection of the Illinois River with Lake Michigan.

The objectives of this study are:

1. To determine the extent of dietary overlap between bighead carp and native filter-feeding fishes in the Mississippi and Illinois river systems.
2. To use data from the Long Term Resource Monitoring Program to examine whether specific environmental factors correlate with successful reproduction of bighead carp in the Upper Mississippi River System.
3. To test the effectiveness of an electric barrier in restricting the spread of bighead carp.

Dietary Overlap

Bighead carp congregate with native filter-feeding fishes in contiguous backwaters during the spring, increasing the potential for competitive interactions. To assess dietary overlap, we collected bighead and silver carp (another introduced Asian carp species, also a filter-feeder), native filter feeding fishes, and zooplankton from contiguous backwater lakes in Navigation Pool 26 of the Mississippi River, and the La Grange Pool of the Illinois River.

Zooplankton and fish samples were collected from nine backwater lakes in the Mississippi River, and eight backwater lakes in the Illinois River. All zooplankton samples have been processed. Although we have not completed analysis of these data, it is clear that zooplankton abundance and composition varied substantially among lakes, which will allow us to examine dietary overlap under a variety of conditions. The total catch of filter feeding fishes from the nine backwater lakes in the Mississippi River was 85 bighead carp, 45 silver carp, 137 gizzard shad, 43 bigmouth buffalo, and 18 paddlefish. Total catch for Illinois River backwater lakes was 87 bighead carp, 1 silver carp, 143 gizzard shad, 79 bigmouth buffalo, and 5 paddlefish. Abundance of bighead carp varied substantially among backwater lakes, which will allow us to examine patterns of native fish diet as a function of Asian carp abundance.

Reproductive Success

All LTRMP fish, habitat, and water quality data have been downloaded and organized into an Access database. Statistical analysis of environmental factors correlated with bighead carp reproductive success will

begin this winter.

Electric Barrier Experiments

Our experimental design consists of 3 treatment levels:

- A raceway containing a functional electric barrier designed to restrict the movement of bighead and silver carp
- A control raceway containing a non - functional electric barrier acting as "sham" control in order to eliminated any bias associated with the physical structure of the active barrier.
- A control raceway having no barrier equipment installed acting as an additional control.

Electric Barrier Operating Parameters

In relation to the active Chicago Sanitary and Shipping Canal Barrier, considerable effort has been put forth to reduce risk to human health in the event that a person passes through the barrier in the water. The result has been fairly detailed barrier specifications including the use of pulsed DC current of relatively low voltage with a very short frequency (~ 2 - 3 Hz / pulses per second) and a pulse duration of 5 - 10 milliseconds long. We have established our experimental field criteria barrier from "real-time" information supplied by Smith-Root, Inc. Electric barrier operating parameters used during our experiments continue to remain well within current operating conditions at the active barrier in the Chicago Sanitary and Shipping Canal.

Experimental Methodology

We attempted to simulate the electric field produced by the active electric barrier in the Chicago Sanitary and Shipping Canal. To conduct our controlled experiments, we have used three 81' long x 8' wide x 5' deep continuous flow outdoor hatchery brood raceways. All barrier equipment used in our study is located at the center of each raceway. Each of the three raceways have held approximately 10 bighead or 10 silver carp (N = ~ 30 fish). Total length of individuals used reflected mean total lengths observed in concurrent field studies. Bighead and silver carp used in our experiments were captured from the Illinois River following standardized collection methods. Fish collected from the river were held in the raceways for at least 12 hrs prior to initiating our experiments. Fish used for one experiment were not used in further experiments in order to reduce potential acclimatization to barrier structure biases. Water depth in each raceway was regulated to a depth of 61 cm! (2 feet).

Each experiment was conducted over a 3 day period to evaluate fish avoidance behavior in the presence of the active electric barrier in relation to the two controls. For a given 3 day period, visual observations involved counting the number of fish above and below each of the three barrier treatment levels (functional barrier, non-functional barrier and control). Observations within a given day were taken and recorded at 15 minute intervals over a 6 hour period for a total of 25 observations per day. Each 3-day experiment was considered to represent one trial. Three trials were conducted for each fish species and barrier type. Response variable data were recorded as absolute counts of fish above and below a given barrier (e.g. 9 fish above out of 10 fish total). Data were transformed to a proportion / percentage (e.g. 0.90 / 90 %) and then arc - sine transformed in order that the data might better conform to assumptions of statistical normality prior to formal analysis. Additionally, the number of fish repelled by the barrier and the number of fish passing through the barrier were also recorded continuously over the 6-hour period across each of the 3 days. Water quality parameters were taken and recorded daily to ensure that similar environmental conditions existed across each of the three raceways.

Problems Encountered

Elevated Illinois River flood - waters in the spring and early summer of 2002 precluded early efforts at capturing necessary numbers of both bighead and silver carp required to conduct our experiments. We also shortened the length of each experiment to three days, as we have been unsuccessful with our attempts to get both bighead and silver carp to feed while in captivity. In addition, we have concluded that the combination of elevated summer water temperatures and prolonged handling appear to be major factors associated with a number mortalities which occurred during our preliminary experimental investigations. However, colder water temperatures have alleviated many problems leading to much greater success in keeping fish healthy during our experiments. We attribute this success to seasonally lower water temperatures and continued efforts to significantly reduce handling time.

Lay Summary

Bighead carp, large, filter-feeding fishes native to Asia, were accidentally introduced into the Mississippi River and established reproducing populations in this system in the early 1990's. Bighead and silver carp (another introduced Asian carp species, also a filter-feeder) are moving upstream in both the Mississippi and Illinois rivers. These non - native fishes will enter the Great Lakes if nothing is done to stop their migration. The diet of bighead and silver carp consists of small aquatic microorganisms called plankton, which they strain from the water column. Concern has arisen in that plankton are also an important and necessary food source for several important native species fish. Additionally, all fishes within the Mississippi River Basin and Great Lakes feed on plankton as larvae and/or juveniles. Therefore, bighead and silver carp may have harmful effects on native fish populations by competing for planktonic prey. Our study will examine 1) dietary similarity between bighead and silver carp, and native filter feeding fishes in the Mississippi and Illinois Rivers, 2) relationships between environmental factors and the reproductive success of bighead carp, and 3) the efficacy of an electric barrier at preventing the spread of bighead and silver carp.

A possible check on the upstream migration of bighead carp and silver carp in the Illinois River has been the construction of an electric fish barrier in the Chicago Sanitary and Shipping Canal at Romeoville, IL. This electric fish barrier was originally intended to block the migration of the benthic round goby (*Neogobius melanstomus*) to the Illinois River waterway from the Great Lakes. Our experiments, which are being conducted in fish raceways at the Jake Wolf Memorial Fish Hatchery (Illinois DNR), are allowing us to evaluate how bighead carp and silver carp will respond to electric barriers similar to the active barrier in Chicago Sanitary and Shipping Canal. Our findings to date indicate that our electric barriers are highly effective in restricting the movement of both bighead and silver carp, although both species of fish are capable of crossing our electric fish barriers when frightened.

International Implications

The majority of fishes that are the focus of commercial and recreational fisheries in the Great Lakes depend on zooplankton and phytoplankton during some portion of their life history. In light of the stress to the Great Lakes ecosystems from previous invasions by non-native species, bighead and silver carp are likely to have negative impacts on both Canadian and United States commercial and recreational activities and on the economies of coastal communities that depend on these resources. Our research will be critical in implementing effective barriers to prevent bighead carp and silver carp from entering the Great Lakes via the Illinois Waterway. In response to our research findings to date, the International Joint Commission (IJC) has contributed funds to bring experts from Fish Guidance Systems Ltd. from the United Kingdom to Illinois to assist us in creating an acoustic / bubble barrier array in order that we might begin investigations specific to objectives 2 - 4. The International Joint Commission is a bi-national organization established by the Boundary Waters Treaty of 1909 to help Canada and the United States prevent and resolve disputes over use of waters along their common boundary.

Media Coverage

To date we have participated in over 48 radio, newspaper and television interviews including coverage by the New York Times, Chicago Sun Times, CNN, FOX and CBS news.

Partnerships

We are working closely with Mr. Jeff Johnson and Mr. Troy Brigham of Smith- Root Inc. and Drs. David Lambert, Jeremy Nedwell and Andrew Turnpenny of Fish Guidance Systems (FGS) Ltd. In addition, we continue to work in cooperation with Illinois Department of Natural Resources, Fisheries Division staff at the Jake Wolf Memorial Fish Hatchery in Topeka, Illinois.

Publications

Chick, J. H. 2002. Asian Carp in the Upper Mississippi River System. Illinois Natural History Survey Report. Spring 2002.

Chick, J. H. Bighead and silver carp in the Upper Mississippi River System and potential threats to the Great Lakes. Presented to the Illinois Waterway Dispersal Barrier Committee in Chicago. January 2002.

Chick, J. H. establishment of Asian Carp in the Upper Mississippi River and potential threats to the Great Lakes. Illinois Waterway Barrier Workshop hosted by the Great Lakes Protection Fund, in Chicago. June 2002.

Pegg, M.A. Evaluation of barriers in preventing Asian carp from entering Lake Michigan. Presented to the International Joint Commission, Chicago, Illinois, August, 2002.

Pegg, M.A. Evaluation of barriers in preventing Asian carp from entering Lake Michigan. Presented to the Electric Barrier Scientific Advisory Panel, Chicago, Illinois, July, 2002.

Undergraduates/Graduates

Schuyler Sampson

Related Projects

An Evaluation of Barriers for Preventing the Spread of Bighead Carp in to the Great Lakes. National Sea Grant College Program, 2002-2004. (\$101,543)

An Evaluation of Acoustic/Bubble Barriers for Preventing the Spread of Asian Carp to the Great Lakes. International Joint Commission, 1 October, 2002 - 31 January, 2003 (\$10,000).

Movement and dispersion of juvenile Asian carp and round gobies. Pending. U.S. EPA, 1 January, 2003 - 31 December, 2004 (\$56,000; Pegg co-PI w/ Uli Reinhardt, Eastern Michigan University).

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Research Information

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- **Initiation Date:** March 1, 2002
- **Completion Date:** February 28, 2004
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