

**Fishing Down the Bighead and Silver Carps:
Reducing the Risk of Invasion to the Great Lakes**

Research Summary

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EXECUTIVE SUMMARY

Abstract:

Bighead carp and silver carp (hereafter, Asian carp) invaded the Illinois River waterway over a decade ago. Populations of these fishes have apparently grown dense in the lower and middle Illinois River and both species are approaching the Chicago Area Waterway System (CAWS) and the defensive electrical barrier. The downriver source populations will continue to send individuals upstream to challenge the CAWS and ultimately the Great Lakes until they are reduced. Research conducted during 2011 determined whether the US government and private industry can “take the fight” to the Asian carp and thereby reduce the risk of a successful upstream breach between the interior riverine watershed and the Lake Michigan watershed in the Illinois River. Similar efforts may be applied to other rivers that pose a risk, such as the Wabash River, which may be connected to the western basin of Lake Erie. Institutions from Great Lakes states (SIUC, MSU, UIUC) collaborated to complete this research. We used telemetry to quantify the movement of Asian carp from the adjacent Mississippi River into the Illinois River, which allowed us to determine the factors affecting upstream movement and the replenishment rate of carp from downstream as they are removed from the Illinois River. The density and biomass of Asian carp and native fishes were unknown in the Illinois River. We conducted the most comprehensive estimate of a main-channel fish assemblage in history using research-grade, down-looking hydroacoustics coupled with other sampling techniques. Mortality and reproductive potential of the Asian carp were determined to assess how resilient Asian carp would be to control by harvest and other methods. Asian carp are believed to negatively affect native fishes. Long-term data were used to appraise this impact, which may also occur in the Great Lakes if a successful invasion occurs. Asian carp are harvested and a market is currently growing. We determined nutrient content, contaminant concentration, and quality of these fish throughout the river. To date, fishing is the only feasible and effective control mechanism in the Illinois River. We conducted research to determine how marketing plus incentives might help facilitate fishing as an effective way to reduce Asian carp while enhancing sustainable harvest of native fishes.

About 30% of Asian carp released into the Mississippi River during November 2010 entered the Illinois River once the river began flooding in April 2011, suggesting that flooding is a cue that facilitates immigration. Of these fish, several individuals moved as far north as beyond Peoria Lock and Dam (about 151 miles) during summer 2011 but apparently not as far north as Starved Rock (river mile 231). These fish returned to the lower Illinois River or vanished from detection. A complementary technique, which provides the history of fish using an environmental chemical signature, showed that about 72% of silver carp and 100% of bighead carp were of Illinois River origin. Most of the Asian carp in the Illinois River were “home-grown”, although immigrants may vary yearly with flow and perhaps density of the populations in the Illinois River. Over 2,100 miles of hydroacoustic survey transects conducted in the main channel of the Illinois River revealed that there were about 2,800 Asian carp per river mile equating to 4,666 pounds of these fishes per river mile. Total standing biomass of Asian carp from Peoria Lock and Dam to the confluence with the Mississippi River was 3.1 million pounds, with silver carp comprising 90% of the density and 70% of the biomass relative to bighead carp. Asian carp made up 63% of the total invasive and native fish biomass, and comprised nearly 100% of all fishes greater than 16 inches total length. Annual mortality of adult Asian carp was 70%. Thus, biomass of Asian carp

produced annually in the Illinois River likely far surpasses 3.1 million pounds when accounting for mortality (e.g., via existing harvest, stranding in drying tributaries, predation) and unsampled areas (e.g., side channels), perhaps reaching 10 million pounds per year. These species can compensate for high mortality by having high reproductive capacity, as long as conditions for spawning and recruitment are favorable in the river (i.e., elevated discharge; see Lohmeyer and Garvey 2009). Immigration also may allow populations to withstand high mortality and maintain standing biomass. Body condition of adult Asian carp (mass at length) was lower than historically reported, suggesting that populations may be near their maximum capacity. Several ecologically and economically important native fish species have declined in the Illinois River since the Asian carps rose to dominance, although the relative impact of effects of Asian carp versus concomitant changes to climate (e.g., record high summer temperatures) and habitat (e.g., backwater sedimentation) are difficult to tease apart. Asian carp were high in protein (56-61%) and fat (10-18%). Fat was high in “healthy oils” (i.e., 20-25% polyunsaturated fatty acids). Baseline estimates of fillet condition suggested that quality improves with catch at colder temperatures. Most fish were low in contaminants (e.g., mercury and PCBs) relative to most consumption advisories. However, some individuals contained contaminant loads that would merit recommendations to limit human consumption. Concentrations of some contaminants (e.g., PCBs, PBDEs) differed between the species and among river pools. Our research experience showed that a market exists for Asian carp, although the infrastructure in the region for capturing, processing, and transporting the fish is poorly developed. Current contracts for shipping whole, flash-frozen Asian carp to China exist. However, Chinese demand appears to depend on exporting large-bodied fish in large quantities (e.g., 30 million pounds), with an apparent premium on bighead carp. We explored the efficacy of converting Asian carp into fish meal, although, logistics were difficult because of lags in developing infrastructure such as an appropriate processing facility. Conversion to organic fertilizer is another viable option, which is already occurring in the region. A pilot incentives program with restricted participation by fishermen resulted in the removal of > 200,000 pounds of Asian carp in fall 2011, producing information about fishing locations, which will be compared to our survey data. In addition to export and meal, marketing research suggested that US consumers across a wide range of demographics are willing to try Asian carp and would be interested in purchasing a value-added product such as fish cakes, particularly if marketed as locally produced. The primary factor inhibiting development of value-added products from Asian carp and native fishes is a lack of infrastructure in the region, not public perception. Modeling of harvest in the Illinois River showed that Asian carp will be quite resilient to fishing unless all sizes of fish are targeted.

This research effort showed that Asian carp densities and biomass in the Illinois River are high, but relative to major fisheries and aquaculture production of the world (e.g., 7.4 billion pounds of silver carp alone) are well smaller than those in fisheries that have collapsed, including the one in the species' native Yangtze River. Thus, it is possible that Asian carp in the Illinois River may be controlled with fishing and other developing control methods. Factors driving a harvest effort must be multifaceted, involving continuous reduction of large adults and small juveniles. Many gaps exist in our knowledge. We do not know how the populations of bighead and silver carp will respond to control (e.g., one may collapse allowing the other to expand). Immigration from the Mississippi River may increase. Our density estimate of Asian carp in the river was conservative because it did not include fish in backwater lakes and side channels, although the survey was conducted when water levels in those areas were very

low or absent and these alternate areas likely were not dominated by Asian carp. Some avoidance of the survey boat also likely occurred. By collecting backwater densities and determining avoidance in 2012, our baseline density and biomass estimate for the Illinois River may increase by as much as a factor of two. Expanded monitoring of extra-channel systems and refinement of current techniques are necessary to gain a more accurate baseline by which we can determine the efficacy of control efforts. Research about the developing market and how it will function to reduce Asian carp while sustainably harvesting the native fish assemblage is necessary for sound control and effective management, ultimately reducing the density of Asian carp approaching the Great Lakes watershed. Simultaneously, tracking the recovery of native fishes and enhancing their success (e.g., through habitat restoration) as well as promoting regional aquaculture of native fishes will be necessary to ensure that the market continues to function after carp are reduced. The goal is that the market for local fish plus other control efforts suppress these invasive species indefinitely and prevent upstream movement toward the CAWS and the Great Lakes.

Introduction:

Bighead carp and silver carp (hereafter, Asian carp) invaded the Illinois River waterway over a decade ago. Populations of these fishes have grown dense in the lower and middle Illinois River and both species are approaching the Chicago Area Waterway System (CAWS) and the defensive electrical barrier. The source populations will continue to send individuals upstream to challenge the CAWS and ultimately the Great Lakes until they are reduced. This follows the “cockroach analogy” in that control of an insect infestation in a home will be ineffective if only the few appearing out in the open are eliminated. Rather, effective control requires eradication at the source, such as in the cupboards or walls. To protect the upstream CAWS and the Great Lakes while ameliorating the problem in US rivers and interior lakes, the populations of carp in the downstream reaches of the Illinois River need to be continually suppressed, including those individuals that migrate in from the Mississippi River.

Asian carp are by far the world’s most cultured fish because they are a healthful source of protein and perhaps omega-3 fatty acids. Thus, unlike so many nuisance or invasive species, these problematic fishes in the US have one positive aspect: they can be converted to desirable food for both human and nonhuman consumption. Organic fertilizer also is a desirable option. The research described herein is designed with one simple idea in mind: to beat Asian carp in the Illinois River and eventually other US waterways by consuming them. Harvesting is an *immediate, revenue-positive complement* to other control efforts, which may be effective but have not yet been developed. Overharvest of Asian carp occurs in their native range and thus is possible in the Illinois River and other waterways of the US. However, several research questions must be addressed to ensure that both public and private resources are expended wisely and efficiently to effectively control these species. This report describes a multi-institution effort to quantify the abundance and ecological impact of these species in the Illinois River and then determine whether fishing is a viable option for control. Successful fishing requires an incentive on behalf of the commercial fishers and processors, because demand and selling price are currently very low. Thus, marketing options need to be identified.

The ecological, fish nutrition, contaminants, harvest, and marketing research began during late 2010 through mid-2011. Funding for this research derived from Cooperative Agreement No. 30181AJ071 between the U.S. Fish and Wildlife Service and the Illinois Department of Natural

Resources. Full pilot results have been collected, although some complementary research will continue through spring 2012. These initial data are being used to direct future research for developing effective control efforts that prevent the spread of Asian carp into the Great Lakes.

Issues and Goals:

- Movement. The Asian carp populations in the Illinois River are not isolated. Populations of both species exist downstream in the Mississippi River and the Missouri River. The contribution of these populations to extant populations in the Illinois River as well as their potential to recolonize during harvest was determined using the most modern forensic techniques available including telemetry and fish microchemistry.
- Counts and biomass. A baseline density and weight estimate does not exist for Asian carp or native fishes in the Illinois River. A starting point is needed to assess whether fishing and other control efforts are working and to evaluate how to improve efforts through time. Density and mass of both species as well as native fishes were quantified with down-looking hydroacoustics and other sampling techniques in the main channel of the lower and middle Illinois River to generate this baseline. Gaps in this approach were identified to refine techniques for future estimates.
- Fishing experiment. Anecdotal evidence suggests that populations of Asian carp are highest in the Peoria and LaGrange reaches of the Illinois River. A contract is in place with a logistics company and a fish processing facility to have fishermen remove about three million pounds of Asian carp from these focal areas. These fish will be converted to meal and used by researchers for experiments exploring Asian carp meal use in animal feeds.
- Environmental impact. The potential impact of Asian carp on the Great Lakes ecosystem can be inferred from their current effect on native species in the Illinois River. Changes in native species and their food were quantified to assess the risk of an Asian carp invasion in the Great Lakes.
- Nutritional composition. The amount of protein and fat in the fillets and bodies of Asian carp is unknown. The quality of the fat such as desirable long-chain, polyunsaturated fatty acids (omega-3) may be high in these fishes. These data were quantified because they provide insight into the marketability of these fish.
- Contaminants. Asian carp may accumulate heavy metals and organic contaminants, affecting their safety for human and animal consumption. The concentrations of these materials were quantified in the fillets and bodies of bighead and silver carp throughout the Illinois River.
- Marketing summit. Although harvest may control these populations, the economic incentive needs to exist to fish them. A summit of private and public groups interested in converting these fishes into products was conducted to assess potential economic pathways. Information from this summit is being used to guide current market development.
- Marketing survey. Asian carp are popular with Chinese consumers. However, their acceptance by US consumers is still unknown, although their economic value in the US as a healthful and ecologically positive domestic product may be substantive. A survey of domestic acceptance was conducted to determine how they might be used in the US.

- Handling and quality assurance. The quality of Asian carp will be affected by many factors such as temperature, handling, and stress during the trip from the river to the end product. The influence of these factors on fillet quality was quantified during fish processing to enhance marketability.
- Incentives. A large, well-equipped fishery for Asian carp is absent in the Illinois River. To aid in the development of a commercial fleet that generates a quality product, a pilot incentives program was implemented for a small number of fishermen.
- Fishing estimate. The amount of fishing necessary to reduce population size and reproductive output of the two Asian carp species is unknown. Information about the populations in the Illinois River was used to determine how much fishing (and other control) mortality is needed and where harvest and other control efforts need to be applied.

Results:

- Movement. One-hundred fifty adult bighead carp and 230 adult silver carp from around Mississippi River Pool 26 were surgically implanted with ultrasonic tags during fall 2010. Immigration was monitored with stationary receivers in the Illinois River extending to Starved Rock at river mile 231. Asian carp did not move into the Illinois River until April 2011, several months after their release. Upstream movement coincided with spring through summer flooding of the Illinois River, consistent with previous telemetry research (DeGrandchamp et al. 2008). About 30% of the Asian carp moved up into the Illinois River, with slightly more silver carp than bighead carp entering the system. Of these fish, the average fish moved 50 miles upstream into the Illinois River. One bighead carp and 6 silver carp moved beyond Peoria Lock and Dam (river mile 158). No fish were detected at Starved Rock Lock and Dam (river mile 231). Of fish that moved far upstream, all that were detected again were found moving back downstream, suggesting that most immigrants did not become residents of upstream pools. Rather, these fishes remained in the lower Illinois River (first 50 miles) after flooding subsided in late summer.
- Environmental history. The water of the Illinois River has a different elemental “signature” than the Mississippi and Missouri Rivers. Thus, the environmental history of bighead and silver carp is recorded in their calcified structures. Data were consistent with telemetry results, with 72% of silver carp and 100% of bighead carp originating in the Illinois River. This means that most of the Asian carp in the Illinois River were spawned there, although some immigrants do contribute to the populations.
- Abundance. Over 2,100 miles of hydroacoustics transects were conducted in LaGrange, Peoria, and Alton reaches of the Illinois River. Fish target data were combined with standardized electrofishing surveys of Asian carp and native fishes. About 30% of the Asian carp were located within the first 15 miles of the Illinois River, which is consistent with our telemetry data. Asian carp were not uniformly distributed throughout the river but occurred in congregations, including the confluence with the Mississippi River and below lock and dam complexes. The three lower reaches contained about 3.1 million pounds of Asian carp, of which silver carp made up about 90% of the density and 70% of the biomass relative to bighead carp. Native fish

biomass comprised about 37% of the fish in the reaches, with Asian carp completely dominating fish greater than 16 inches total length. These estimates are likely low by as much as a factor of two because sampling did not occur in backwaters, up tributaries, or in shallow locations (< 3 feet). However, densities of silver carp overlapped with those of previous estimates in the LaGrange Reach (Sass et al. 2010). Future research requires sampling of extrachannel areas in addition to continued monitoring of the main channel populations. Also, this estimate is for current biomass but does not account for annual mortality (including harvest) and immigration. The annual production of Asian carp in the Illinois River may be greater than 10 million pounds.

- Demographics of Asian carp. Demographics data including growth, age, and mortality are essential for estimating how the populations will respond to control efforts. Annual mortality was about 70%, consistent with historical data. However, condition quantified as body weight at length was lower than historical estimates, suggesting that the populations may be near their carrying capacity in the river. Females had extremely high gonadosomatic indices, consistent with previous research. Reproductive potential is quite high, requiring a removal of a high proportion of biomass to effectively reduce populations.
- Fishing experiment. A contract for the removal of about 3 million pounds of Asian carp from LaGrange and Peoria reaches of the Illinois River has been awarded and is underway. About 40,000 pounds of fish have been removed to date. Additional fishing is occurring in 2012. These fish will be converted to dried meal for research into the inclusion of meal into animal feeds. Given the biomass estimate from acoustic surveys, this effort should dramatically affect the populations in these reaches. If successful, the effect should be measurable with surveys. Fishing was slated to be completed by December 2011. However, logistic problems occurred, delaying the effort. Through deliberation and research, the logistic issues have been resolved and should lead to a fish meal industry for Asian carp, other invasive species, and native fishes in the region.
- Environmental impact. Zooplankton is important for nearly every fish species in the Illinois River during early life. Long-term data for the Illinois River show that zooplankton assemblages have shifted from cladoceran-dominated to rotifer-dominated in the LaGrange reach. Rotifers dominate all zooplankton assemblages in the river, with total zooplankton density declining in reaches north of Peoria Lock and Dam. Low zooplankton density may limit growth of Asian carp in northern reaches and may explain why tagged carp did not move farther upstream (i.e., less food = less inclination to move upstream). Long-term catch rates of several native fish species have declined in LaGrange reach during the past decade including gizzard shad, black crappie, freshwater drum, sauger, bigmouth buffalo, and white bass, perhaps due to poor availability of properly sized zooplankton during early life. Removal of Asian carp may allow recruitment of these species to rebound.
- Nutritional composition and quality. Nutritional composition of Asian carp was similar among reaches of the Illinois River, although fish from Peoria Reach were leaner. Perhaps food resources were more limited in this reach than others leading to less fat content. Silver carp were comprised of 18% lipid and 56% protein. Bighead carp were leaner with 10% lipid and 61% protein. Fat content increased with body length in both species. Both species produce a fish

meal equivalent in composition (and value) to other meals on the market. Shelf-life of meal stored at about 50°F is limited to less than a month. A stabilizer will need to be added to prolong the quality of the meal. The lipids of Asian carp are high in polyunsaturated fatty acids (up to 25%). Fillet quality (whiteness and pH) varied among individuals, with fish caught at coldest temperatures (10°F) having the highest apparent quality.

- Contaminants. Contaminant concentrations varied among individual Asian carp and were generally low. Heavy metals such as mercury were generally low in these fish, although a few individuals (about 10%) had concentrations that mandated limited consumption by sensitive people (e.g., pregnant women). Metal concentrations were low relative to most commercially important fish species. Organochlorine pesticides (e.g., chlordane) were present in some fish at low concentrations with the highest occurrence in northern river reaches. Concentrations of PCBs were below the FDA action level for fish and were generally low compared to most commercially available fishes. Other contaminant concentrations were low as well.
- Marketing. A 2-day summit convened at the Great Rivers Research and Education Center during fall 2010. A network of experts from eight states from both private and public sectors was developed and is being used to develop economically viable ways to exploit Asian carp in the Illinois River and other river systems in the US. Summit results can be obtained at http://www.iiseagrant.org/catalog/ais/asian_carp_summit.html. Chinese demand for whole, flash-frozen Asian carp exists. However, infrastructure for processing these fish and transporting them has lagged. Cost, difficult logistics, and demand for large-bodied fish will likely limit the ability for this market pathway to effectively control carp in the Illinois River. Fish meal and organic fertilizer are likely going to be the primary paths by which multiple sizes of Asian carp can be processed into a marketable and profitable material that can be quickly absorbed into US industry. In addition to meal, Asian carp and native fishes may be converted into a value-added product such as fish cakes. Consumer taste-tests of these cakes prepared by Chef Philippe Parola have been positive. An unbiased marketing survey conducted throughout the US demonstrated that, of consumers that eat fish regularly, health and taste were the primary factors affecting their choice of fish product. Of the respondents, 73% were willing to try Asian carp. The majority (58%) of consumers did not think that a rename of the fish (e.g., to silverfin) was necessary. Local availability was important to the respondents. Estimated cost of a processing plant to produce a value-added product from Asian carp and native species would be about \$10 million. Unlike fish shipped to China or absorbed into the domestic fish meal market, the value-added product would likely have greater regional economic impact (e.g., from combined fishing, processing, shipping, marketing, and sales throughout the region). Although respondents of the survey did not say that environmental issues influenced their choice of fish, Asian carp could be marketed as an environmentally friendly food choice. Sustainable harvest of native fishes (and local aquaculture) could replace Asian carp as densities of the invasive fish decline. For example, aquaculture in Illinois generates greater than \$2 million annually and has tremendous potential for growth, with proper marketing and distribution.
- Incentives. A pilot program involving 10 fishermen and a crew member was conducted during fall 2011, resulting in the removal of about 200,000 pounds of Asian carp from the Illinois River.

Data on fishing locations were collected and will be used to better understand patterns of fishing in the river and direct management in the future. Although obviously popular with fishermen that target carp, the incentives program was not viewed favorably by other “non-carp” commercial fishermen because of the perception that the incentives was creating pressure for sustainable populations of Asian carp in the river.

- Fishing estimate. Stochastic simulation modeling of fishing effects on populations of Asian carp in the Illinois River showed that fishing and other control efforts targeting only small or large fish will not control them, confirming results of previous research. Rather, all sizes of Asian carp must be harvested. This can be achieved with a fish meal market as well as a value-added market where small fish as well as large ones can be converted to a saleable product. A market based on selling only large fish will not control the populations.

Conclusions and Directions:

We have learned much about Asian carp in one year, producing a baseline by which the efficacy of control efforts may be judged. The source populations for bighead and silver carp appear to be in the Mississippi River and the lower Illinois River, with individuals moving upstream during floods. Control may be most effective when these fish are congregated during low flow periods and less dispersed. Research confirmed that these species have life histories that make them resilient to high adult mortality. Sources of mortality likely include the growing fishery that already exists in the Illinois River as well as stranding in drying backwater lakes and tributaries. Mass mortality occurred during the record high temperatures of summer 2011, where thousands of carp carcasses littered dried stream beds. Mass fish kills are not uncommon for these species in the main channel, although the causes are unknown.

Although we have provided the most comprehensive estimate of density and biomass of Asian carp in a large river, we acknowledge that gaps exist in our knowledge. The hydroacoustics gear we used was limited to water > 6 feet deep. A method (i.e., side-looking, split-beam hydroacoustics) that allows us to sample shallow areas as well as tributaries and lakes is needed to refine our estimate. In 2011, immigration into the river was common and upstream movement occurred. However, we do not know how immigration varies among years and whether under some conditions, adults remain in upstream locations. This may depend on many factors including reach-specific density of fish and food availability. This information needs to be collected through time to better direct control efforts.

The impact of Asian carp on local fishes and zooplankton food resources may be dire. As Asian carp are reduced through harvest and perhaps other control efforts, the response of the native assemblage should be positive. However, other factors also may be reducing native species. Quantifying the responses will be important for assessing recovery. For example, in addition to removal of carp, improvement of river habitat will likely be necessary.

To control Asian carp and keep them from continually challenging the Great Lakes watershed, source populations will need to be suppressed indefinitely – a long-term commitment. Our research suggests that a developing market may be able to control these fish. However, because total biomass of Asian carp in the Illinois River is relatively small compared to many other fisheries, other fish products will need to be present to help maintain market demand and keep Asian carp suppressed as they

immigrate from the Mississippi River and as recruitment in the Illinois River fluctuates. Biomass of native fishes is high and aquaculture production can grow. These alternative fish sources may be able to sustain the market, allowing it to be sufficiently flexible to respond to “flare ups” of Asian carp.

Another method for removing carp is directly contracting fishermen to harvest carp through time. The incentives program promoted removal of Asian carp and an experimental fishing effort is underway and successfully removing carp from the river. An agency supported effort combined with the engagement of private industry might be the best way to control Asian carp. Our research shows that a fish meal market plus the development of value-added products from Asian carp, native fishes, and native aquacultured fish are viable, if marketed and promoted properly and effectively in the region. The low contaminants and high quality of these fishes need to be lauded, especially relative to many commercially available fishes (e.g., tuna). Limitations of the export demand for Asian carp (e.g., large size of fish) will limit control Asian carp in the Illinois River.

A concerted, long-term research effort is needed to inform management. Refinement of the survey effort is needed as well as a continued multi-year monitoring effort to assess the effectiveness of controls. Immigration into the Illinois River and within-river movement and establishment likely varies among years. We need to determine how the 2010-2011 patterns fall within average among-year dynamics in the river. Quantifying inter-annual patterns of distribution of all ages and sizes of Asian carp will allow managers to help direct fishing and other control methods (e.g., perhaps water cannons) toward areas of aggregation.

If a market model is going to work for control, then a commitment to assessing the value of native fishes and aquaculture of native fishes in the developing market as well as that of the Asian carp is going to be necessary. Simply put, there likely are too few Asian carp in the Illinois River to encourage a long-term market but likely too many for public-sponsored control by agencies to be cost-effective and maintainable. Determining the potential sustainable productivity of native fishes and other invasive species (e.g., common carp, grass carp) in the region along with their suitability and safety is going to be needed to make harvest a suitable option for long-term control. Research into the bioeconomics of such a complex market and its acceptability to US consumers will be necessary to fully evaluate this issue.

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