Great Lakes Sea Grant Network

EDUCATION AND OUTREACH ON ASIAN CARP

In Support of the Asian Carp Regional Coordinating Committee

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Great Lakes Restoration

Contents

For more information on the developers of this document, visit these websites:

Asian Carp Regional Coordinating Committee (ACRCC)
asiancarp.us

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Understanding the Threat

Current and Future Research in Asian Carp Management and Control

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INTRODUCTION

THE THREAT

The term Asian carp can evoke images of dozens of large fish leaping from water, startled by boat engines and colliding with boats and people. The fish in these well-known videos are predominantly Silver Carp (***Hypophthalmichthys molitrix***), though the broader term, Asian carp, includes three additional non-native carp species of Asian origin currently in North America: Bighead Carp (***Hypophthalmichthys nobilis***), Grass Carp (***Ctenopharyngodon idella***), and Black Carp (***Mylopharyngodon piceus***). Unfortunately, these invasive fish present more concerns than just the threat of injury to recreational boaters. Asian carp were brought to the United States in the 1960s (Grass Carp) and 1970s (other three species) for use in aquaculture, but these species eventually made their way to the Mississippi River watershed and have been expanding their range since. Silver and Bighead Carp feed on plankton by filtering it out of the water (filter feeders), while Grass Carp eat vegetation and Black Carp eat mollusks, like clams and snails. Asian carp are voracious and often outcompete native fish for food and habitat, which is of great concern to wildlife and resource managers. Due to their potential negative impacts, Bighead, Silver, and Black Carp are now listed as "injurious" species by the U.S. Fish and Wildlife Service, which can invoke legal transportation limitations. The movement of Grass Carp is regulated by many individual states as well.

When discussing the threat to the Great Lakes, Silver and Bighead Carp are

Silver Carp

Bighead Carp

Grass Carp

Black Carp

commonly referenced as these are the two species moving up the Illinois River toward the Chicago Area Waterways System (CAWS). The CAWS connects the Mississippi River basin to the Great Lakes through a series of canals used for shipping, storm and wastewater discharge, and recreation. Additionally, Grass Carp are already present in the Great Lakes watershed, and there is evidence of successful Grass Carp spawning in the Sandusky River, a Lake Erie tributary. Black Carp are found in the Mississippi River, currently near the Iowa-Missouri border, but they are moving north toward new habitats.

WHY THE CONCERN

Aside from the potential bodily harm that Silver Carp can cause to boaters, the ecosystem impacts that these four species are having in their current range will occur to varying degrees in the Great Lakes if they become established. The primary concern is that Asian carps will impact the already stressed Great Lakes food web. Once these fish become established, impacts to native species will likely occur directly through competition for food, or indirectly though changes to the food web. In parts of the Illinois River, Silver and Bighead Carp are now the dominant fish species, making up more than 90% of the fish biomass. Both species are filter feeders that compete with other fish that feed lower on the food web, such as forage fish (such as minnows and shad), young sport fish, and other commercially important species. All four non-native carp species are also fast growing and can quickly escape predation. In ideal conditions, they can grow large enough in their first year to no longer be vulnerable to most predators.
The location of the Silver and Bighead Carp invasion front in the Illinois River is currently the Dresden Island Pool of the Des Plaines River, which is about 18 river miles downstream from the Electric Dispersal Barrier and 55 river miles from Lake Michigan. Although Silver and Bighead Carp receive much of the media focus, Black and Grass Carp are also a threat to native species and ecosystems, as well as recreation and economies.

Provided here is brief synopsis of project information derived from visits and interviews of ongoing research to control and manage Asian carp. The research is divided into Life History, Movement and Behavior, Prevention and Control, Ecosystem Changes, and the Great Lakes, and concludes with Knowledge Gaps.

LIFE HISTORY

Asian carp spawning occurs in rivers, and water flow is an important component of the life cycle. Eggs are fertilized upstream, the eggs hatch and the larvae drift downstream until they are developed enough to swim on their own. Water velocity and length of the river are critical because if the larvae reach a slow part of the river or a lake before they are fully developed, they could settle to the bottom and die.

Telemetry studies may help to identify Asian carp spawning cues and spawning locations. A researcher at University of Illinois Urbana–Champaign, Tatiana Garcia, developed the FluEgg model to illustrate the movement of eggs through a river system. This model can be customized to test various scenarios for individual river systems (see a video of FluEgg in action: **bit.ly/FluEggVideo**). In the Great Lakes, researchers at the US Geological Survey (USGS) studied the spawning requirements of Asian carp and identified rivers where spawning could most likely occur (Elizabeth Murphy and others; **bit.ly/GLcarpSpawning**). Work on the Wabash River by Reuben Goforth (Purdue University) indicates that one expected spawning cue, increased stream flow, is not as important during a low flow drought year where eggs were present most of the summer.

Little is known about the early life history of Asian carp and a better understanding is needed to make management of these species more efficient. Juvenile Asian carp occupy shallow habitats and backwaters in the riverine environment. As the fish get older, they move into deeper water. USGS researcher Duane Chapman is conducting research on survival, depth, and predator density in the habitat of juvenile fish. It is challenging to find young fish because of their small size, but with methods like microchemistry, researchers like Greg Whitledge at Southern Illinois University Carbondale can determine the origin of an adult fish by examining ratios of inorganic elements in the otolith (ear bone). Other researchers are leading work on early life history, including on the Sangamon River by Robert Colombo (Eastern Illinois University).

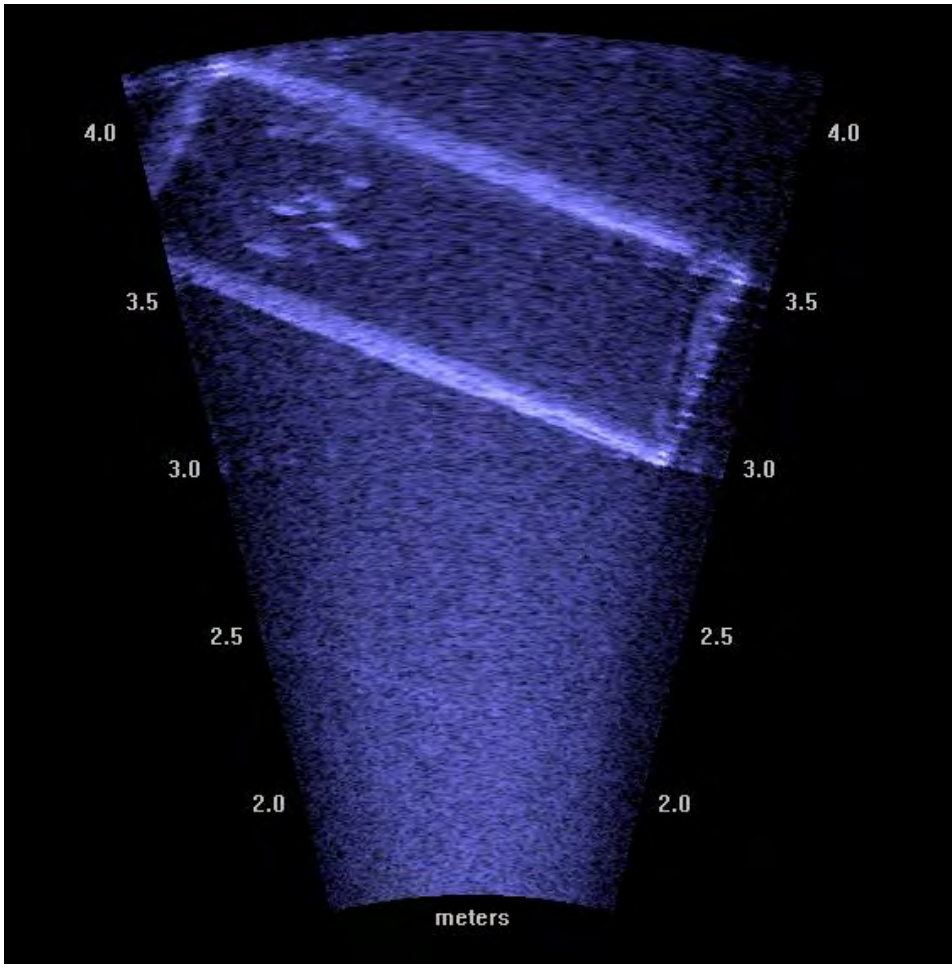
MOVEMENT AND BEHAVIOR

There are a number of projects currently underway to monitor the movement of Asian carp to create a better understanding of when and why they move. Different methods and technologies are used to track fish movements. Tags used to track fish can be as simple as a metal band on the fish's jaw. This kind of tag only provides information about release location and capture location, not about where the fish traveled in between. Researchers are using advanced techniques, such as implanted acoustic tags, sonar, and even the ear bones of the fish themselves, to determine where the fish are and when. There is no single best method for tracking movement; a combination of these methods provides a more complete story of these species' biology and life history.

Acoustic tags implanted in fish send signals that are recorded by researcher-operated hydrophones or by remote receivers that log the data. Marybeth Brey and Ruairi MacNamara (Southern Illinois University Carbondale) used this method to tag Silver and Bighead Carp in the Illinois River near Starved Rock for their research. To capture fish for tagging, commercial fishers contracted by the State of Illinois set gill nets and herd carp into the nets by making noise with their boat engines and banging on the side of their boats. The fish in the best condition are taken back to land to have jaw tags attached and the transmitters implanted. Jaw tags identify fish with acoustic tags; if a commercial fisherman captures a tagged fish, they can remove the jaw tag before releasing the fish and then return the tag to the researchers for a reward. Receivers at narrow points

in the river record the date and time each tagged fish passes. The data are then downloaded to create maps of the fishes' movement patterns. The U.S. Fish and Wildlife Service (USFWS) and Quinton Phelps with the Missouri Department of Conservation (MO DOC) are conducting similar research on the Upper Mississippi River. Researchers hope to learn how far and how often these fish are moving and where they are spawning. Once the movement maps are created, potential cues for movement will be identified, such as which environmental factors indicate to the fish that it is time to spawn. Understanding these behaviors can lead to more effective and efficient management.

Sonar provides another method to find and track the movements of fish. Anglers may be familiar with this technology in the form fish finders, but new research instruments are providing higher quality images of fish movement and behavior. An example of high-resolution DIDSON sonar is available in this video: **www.youtube.com/watch?v=Nlki5qivvxg** while a photo is available at **bit.ly/2l1haNV**. Aaron Parker (USFWS) uses DIDSON sonar to study the behavior of fish at the site of an electric fish dispersal barrier on the Chicago Sanitary and Ship Canal. Sonar is particularly useful at this site because the depth, rectangular shape and commercial navigation in the canal make using nets to effectively survey fish difficult. MacNamara is using DIDSON in hopes of being able to identify Asian carp based on the acoustic signature. David Glover (The Ohio State University) analyzed the unique echo provided by the Asian carp swim bladder to help make species identifications possible using multi-frequency sonar. Sonar monitoring is potentially an efficient monitoring



tool to supplement the effort required to net fish. Sonar can also show the spatial distribution of individual fish and their behavior in response to external cues.

Tracking the movements of immature fish is a challenge because they are often too small to tag or cannot be located with conventional sampling methods. Greg Whitledge (Southern Illinois University Carbondale) is using otolith microchemistry to identify the spawning grounds of Grass and Black Carp. The otolith, or ear bone, of a fish grows with the fish by adding material on the outside of the bone, like tree rings. Because of

this growth pattern, the center of the bone is formed during the early life of the fish. The fish incorporates chemical elements from the environment into the bone structure and therefore, the ear bones of a fish contain an environmental "record" of where the fish lived. Analyzing the rings, researchers like Whitledge can detect distinctive ratios of elements from regional streams and compare that to the microchemistry of the otoliths to determine where the fish spent the early part of its life. This method has been used as one of the pieces of evidence confirming the spawning location of Grass Carp in the Sandusky River, a tributary of Lake Erie.

More about additional research on the movement of these species by Robert Colombo, Eastern Illinois University, and Reuben Goforth, Purdue University, is available online.

MONITORING/eDNA

Monitoring is an important part of the Asian carp research program because managers need to know current abundance and location, as well as new locations they may be moving towards. Researchers are using traditional monitoring methods, such as nets to catch Asian carp, in addition to molecular techniques that target and identify the fish's DNA in the water. Fish and other aquatic organisms shed DNA continuously in the form of slime, scales, blood, waste, and other detritus. Environmental DNA, or "eDNA," is collected in a water sample from a river or lake. The eDNA is then extracted from the water sample and, using a process called polymerase chain reaction (PCR), scientists replicate the eDNA to determine the species of origin.

A great deal of research is ongoing to utilize and improve eDNA as a monitoring

tool. At the University of Notre Dame, Christopher Jerde initiated its use for monitoring the presence of Asian carp and its ability to determine the presence of both native and invasive species. James Casey and Rod Getchell (Cornell University) recently developed a quantitative PCR (qPCR) method for testing eDNA, a faster and less expensive method. Working with Illinois-Indiana Sea Grant, Jerde used the eDNA process to test water from bait shop tanks to see if Asian carp DNA might be present with bait minnows. He also helped design effective outreach materials to reduce the risk of bait-related transfers of carp and other invasive species. Jerde is also working with Mark Gaikowski (USGS) to develop a handheld PCR device for rapidly testing for eDNA in the field. This does not replace the more precise laboratory-based methods, but is a useful tool for making decisions in the field without waiting weeks or months for test results. Emy Monroe (Whitney Genetics Lab, USFWS) worked with eDNA testing labs at USGS and US Army Corps of Engineers to test new eDNA markers for identifying Asian carp more effectively using different segments of DNA than those currently used.

Researchers are also applying eDNA testing to questions about biology and management. Duane Chapman (USGS) sees potential in sampling eDNA in many locations in a river to identify spawning sites based on concentration of milt (fish sperm). When Asian carp spawn, they broadcast their milt and eggs into the water, so during these times the concentrations of DNA in the environment is high and locations with the highest DNA concentrations would indicate where spawning is taking place. Other research is focused on how eDNA concentration relates to the number of fish in an area or how much DNA a live fish loses to the environment (DNA shedding). Intensive, paired eDNA sampling and netting in the Wabash River is conducted throughout the year to inform scientists about the ecology and seasonal distribution of Asian carp.

Wen-Tso Liu (University of Illinois Urbana–Champaign) is investigating methods to identify Asian carp location using microbes in the intestines of the fish. This test could complement the current eDNA testing regime. It works because the bacteria living in the gut of Asian carp have a unique DNA profile as compared to native species, and there are many more bacterial cells coming from the Asian carp gut and feces into the environment than eDNA that is shed in the form of cells from the fish itself. This combination of factors makes this a useful test to help identify the presence of these non-native species. Dr. Liu identified patterns in the DNA profiles of gut flora for the most common native species in rivers where Asian carp are found and determined that the invasive carp have a different DNA profile patterns of gut flora compared to native species.

The USFWS is using eDNA, telemetry,

and sonar in the Ohio River to monitor Asian carp in that watershed. Additional work to use and improve the eDNA process for monitoring is underway by Lindsay Chadderton (The Nature Conservancy) and Matt Barnes (University of Notre Dame).

The current process for eDNA analysis has some drawbacks. It is possible for eDNA to be transported by flowing currents or predators (feces), consequently the location of the actual fish compared to where the eDNA was sampled may not be so close. The presence of eDNA also does not reveal what life stage the fish was in, or whether it was dead or alive. Additionally, eDNA degrades quickly in water, thus it can only reveal a short time frame of possible fish presence. Even with these drawbacks, though, the potential for this technique to detect an elusive fish with ease at a relatively low cost and amount of effort, makes eDNA an efficient complement to traditional surveying methods.

PREVENTION AND CONTROL

Keeping invasive species out can be less costly (environmentally and economically) than trying to control species populations once they are established in a location. Therefore, much work is ongoing to keep Asian carp out of the Great Lakes. These methods may be used to keep fish out of an area or make it easier to capture and remove fish. Capture and removal of fish in areas where they are established helps reduce the risk of them expanding into other areas.

BARRIERS AND REPELLANTS

The primary structure currently preventing the movement of Asian carp into the Great Lakes is an electric dispersal barrier in the Chicago Sanitary and Ship Canal (part of the CAWS) near Romeoville, Illinois. The barrier uses a graduated electric field to repel fish from moving upstream; when the fish swim far enough into the electric barrier array, it stuns them and they float back downstream. Asian carp are not abundant at the barrier; the "front" of the main population is 18 river miles downstream in the Dresden Island Pool. Several studies examined the barrier's effectiveness and potential weaknesses. The USFWS conducted a study in which they transported fish (Gizzard Shad) in PVC cages through the barrier to assess how boats affected the electric current's effect on the fish. They found a level of interference with the electric current, which could allow some passage of fish upstream through the barrier, especially smaller individuals not as readily affected by the electric field. Another study at the barrier by Aaron Parker (USFWS) used

DIDSON sonar to look at fish behavior (Gizzard Shad again) in relation to the barrier field in turbid (muddy) water. The fish appear to constantly challenge the barrier but are stunned and drift downstream. Assuming Asian carp would behave similarly emphasizes the need to keep the barrier working.

Multiple new potential tools for prevention and control are being tested in a backwater of the Illinois River, near Morris, Illinois, using the Integrated Pest Management process (see podcast **bit.ly/CarpIPMpodcast**). The trials allow for management agencies to see the full range of options that are available and allow them to decide what would be most effective in their areas. Trials conducted in 2013 combined waterguns, algal attractants (Ed Little, USGS), and commercial harvest methods to determine their impacts on abundance and density of Asian carp. Waterguns create a sonic pressure wave underwater that can repel or even kill fish. USGS Illinois Water Science Center researcher William Morrow conducted trials of this technology at the Upper Midwest Environmental Sciences Center (UMESC) to determine its impact on structures like canal walls. Ryan Adams (UMESC) conducted similar trials focused on the shape and size of the pressure wave in ponds at the Morris, Illinois site. Algal attractants use the Silver and Bighead Carp's planktonic food to attract them to specific locations where they can be more easily targeted for capture (Ed Little, USGS). David Glover and Elizabeth Marschall (The Ohio State University) assisted with the evaluation of the trial outcomes.

Cory Suski (University of Illinois) is investigating carbon dioxide (CO_2) as a possible tool to repel Asian carp. Fish avoid areas with high concentrations of CO_2. Carbon dioxide is useful because it is inexpensive; however, its effects are not species specific and consequently it could influence the behavior of native species. It is also not 100-percent effective at repelling all individuals. Thus, CO_2 is potentially useful in combination with other tools.

Peter Sorensen (University of Minnesota) is working on prevention methods to keep Asian carp from moving up the Mississippi River and to minimize the invasion of waterways within the state of Minnesota. One method Sorensen is investigating is sound. Asian carp are more sensitive to sound than many native species, so the right sounds or frequencies may prevent movement upstream, especially around locks. Locks are a good location to focus sound-related efforts because they are narrow and force fish into a confined space. Sorensen is also studying the swimming performance of Asian carp, which may help in designing structures to increase flow in critical areas when these species are moving upstream.

HABITAT AND PREDATION

Additional research considers the role of habitat in preventing Asian carp establishment. Jon Amberg (USGS) suggested that restoring and creating habitat could encourage species that could be predators on Asian carp eggs, larvae, and juveniles. Predator fish, such as Northern Pike and Walleye, could be added or their populations enhanced to prey on the small Asian carp. Habitat restoration would have benefits to society in addition to helping control aquatic invasive species. A more diverse and healthy ecosystem are thought to be at less risk of invasion than impaired ecosystems.

CAPTURE

Capturing Asian carp with nets is one of the main methods used to monitor and reduce populations. Commercial fishers have been working on the Illinois River to remove many Asian carp and this activity is helping to limit population expansion near front of the invasion, reducing the risk that they will move upstream.

At the Illinois Natural History Survey (INHS), Steve Butler tested different kinds of nets to assess the efficiency and selectivity of nets for larval, juvenile, and adult Asian carp. It is important to understand the bias, or uncertainty, associated with different types of sampling gear to fully interpret monitoring results. Examples of bias are when some species are more likely to be captured than others, or when some species, like Silver Carp, can avoid nets. Without understanding these factors, it is difficult to accurately estimate the size of fish populations. Researchers are trying to locate important Asian carp habitat to improve the effectiveness of capture efforts. They are using "Judas fish," which are tagged Asian carp or Common Carp, to lead them to important habitats. Multiple projects using this method are underway by Duane Chapman (USGS) and Peter Sorensen (University of Minnesota).

Once the fish are captured, there are few options for their use. Expanding the market for Asian carp could help support a commercial fishery; however, there are risks associated with creating commercial markets for an invasive species. If a species is considered valuable, this may become a reason not to continue with prevention and control efforts, or it may drive individuals to move the species around to new locations to create new markets. Quinton Phelps (MO DOC) suggests that better control of populations could be achieved by targeting smaller, less marketable Asian carp. Smaller fish may be turned into high quality fertilizer for gardening, processed into fish products, or used for pet food.

REMOVAL

Other approaches to managing the Asian carp threat focus on developing new techniques to target and more effectively kill Asian carp. At the Upper Mississippi River Environmental Science Center in La Crosse, Wisconsin, the USGS is trying to identify and exploit vulnerabilities in Asian carp biology. This effort is modeled on the approach used to control Sea Lamprey populations in the Great Lakes. The goal is to find a species-specific chemical that targets Asian carp, like the toxicants used to target Sea Lamprey, and have limited impacts on native species. There are only a limited number of known fish toxicants, but Terry Hubert (USGS) is investigating an extensive list of chemicals developed in the last several decades but not yet tested as potential fish toxicants. There are large databases of chemicals maintained by chemical companies, many under patents, that USGS will screen to identify chemicals with similar structures to current fish toxicants. The hypothesis is that new chemicals with similar molecular structures to current fish toxicants may also be effective at killing fish. After narrowing the list to a subset of promising candidates, the new chemicals can be tested as selective fish toxicants and eventually tested on Asian carp. This is a long-term project with many regulatory hurdles to pass before the new chemicals can be used in rivers and streams. One of the currently available fish toxicants, rotenone, was used to kill Asian carp in the CAWS system. Ryan Jackson (USGS Illinois Water Science Center) studied how hydrology of the river influences movement of the toxicant to aid the efficiency of applications.

Researchers are also working to exploit the filter feeding behavior of Silver and Bighead Carp as a delivery mechanism for the poison. Jon Amberg (USGS) is working to develop several different types of microparticles that can deliver poison to Asian carp. These plankton-sized particles are currently used in other applications, such as to deliver nutrition or drugs to small fishes in marine aquaculture. Once a fish ingests the particle during feeding, the poison releases in the gut. Targeted killing of Asian carp would be most efficient in areas where they make up a bulk of the fish population to limit potential impacts on other species. Future work could use species-specific coatings for the poisons that only Asian carp would be able to digest and leave other species unaffected. This specificity may be possible because of the differences in digestive enzymes between Asian carp and native species.

Pathogens present another potential future opportunity to eradicate Asian carp. Some may already be impacting Asian carp, as evidenced in the April 2014 die-off of hundreds of thousands of Silver Carp in Kentucky, some of which outwardly appeared to be sick. Researchers are studying the pathogens currently infecting these species. Nick Phelps (University of Minnesota) is screening Asian carp for pathogens to create a baseline of health for these species. This work will also help identify pathogens that Asian carp may be carrying that could be a risk to native species. Jon Amberg is collaborating with Maria Sepúlveda (Purdue University) to use DNA sequencing technology to identify pathogens in Silver and Bighead Carp of the Wabash River.

ECOSYSTEM CHANGES

A major impact of invasive species is the ecosystem changes they can cause through factors such as habitat alteration or competition for resources. Research on the interactions between Asian carp and native species is taking place in small enclosures, experimental ponds, and open rivers. Quinton Phelps (MO DOC) is part of the Long Term Mississippi River Monitoring data effort that shows a reduction in number and condition of native species (Gizzard Shad and Bigmouth Buffalo) when Silver and Bighead Carp are present. Phelps also observed changes in Mississippi River floodplain ponds following the 2011 flood. Due to the flood, some ponds had Silver and Bighead Carp and some did not. Native species were adversely affected in the ponds with a high number of Asian carp, but the mechanism for this change is not fully understood.

Marybeth Brey (Southern Illinois University Carbondale) conducted trials in ponds under five experimental conditions: no fish, Bighead Carp, Silver Carp, Gizzard Shad, and Gizzard Shad/Silver Carp, to study the changes in chlorophyll, nitrogen, phosphorus, phytoplankton, and zooplankton. The research will provide insight into the differences in these variables between Silver and Bighead Carp, as well as potential facilitation between Gizzard Shad and Silver Carp where Silver Carp may actually have larger impacts in the presence of Gizzard Shad. INHS graduate student Kirsten Nelson used small enclosures called mesocosms to understand fish growth in the presence of Asian carp. Andrew Casper (INHS) is studying the changes in the Illinois River zooplankton community structure between pre-Asian carp, post-Asian carp, and with commercial Asian carp fishing. Duane Chapman (USGS) suggested competition as a potential mechanism of impacted native fish assemblages because Asian carp diets overlap with zooplankton (fish prey) and some larval fish. This could impact Great Lakes species, such as Yellow Perch, Lake Whitefish, and other sport and commercially valuable fish. Teasing apart the mechanisms associated with fish interactions is a challenge but it is useful to understand why changes in the food web occur in order to predict potential ecosystem changes and species interactions in areas at risk of invasion.

GREAT LAKES

Many researchers are currently trying to predict the potential impacts of Asian carp on the Great Lakes. Researchers have already identified potential spawning rivers (Elizabeth Murphy and others) and Michael Hoff (USFWS) has modeled the potential range of Asian carp in North America based on their native range. This model shows that the Great Lakes are at risk of invasion from all four species. Duane Chapman (USGS) believes that potential nursery habitat should be identified in the Great Lakes, such as coastal wetlands and drowned river mouths, which young Asian carp would likely utilize as they drift from spawning rivers into the lake. Grass Carp, which feed on aquatic plants, could adversely impact Great Lakes coastal wetlands. This in turn could impact Great Lakes fisheries because coastal wetlands are important habitat for many Great Lakes fish species at some stage in their lives.

Changes in the planktonic food web in the Great Lakes because of the zebra and quagga mussel invasion limits the food available for Asian carp. However, Duane Chapman suggests that Asian carp could survive on quagga mussel veligers (larval mussels) and mussel pseudofeces (unpalatable food and other materials). Asian carp may also be able to stir up sediment and feed in the sediment cloud. There is much uncertainty about the potential Asian carp population abundance in the upper Great Lakes (Superior, Michigan, Huron), though Lake Erie may be a very suitable habitat for Asian carp.

KNOWLEDGE GAPS

We asked researchers to share what needs exist to better understand Asian carp and make progress in preventing, monitoring and controlling their populations.

OUTREACH

Outreach is a critical element to prevent, slow and minimize the impacts of Asian carp. Shutting down the pathways through education combined with regulation and enforcement have been largely effective in preventing establishment of Asian carp in the Great Lakes and the adjacent watershed. Natural resource and social research is needed to facilitate a better understanding of Asian carp management by the legislatures and members of the public.

What does control of Asian carp mean? The term "control" may be misleading to the public because we will never eradicate Asian carp, rather we can hope to manage their populations at acceptable levels (see Great Lakes Sea Lamprey example). (Jon Amberg, USGS)

Eat more Asian carp! Marketing and consultation with social scientists is needed to encourage consumption of Asian carp. Asian carp food trucks could help build more interest in eating this species. Blind taste tests could be used between Asian carp and other common species like tilapia and catfish. Markets can be better supported by promoting Asian carp as a healthy alternative to more commonly consumed freshwater fish fillets. (Quinton Phelps, MO DOC)

Understanding egg transport model and early life history. There is a need for better outreach on how the FluEgg model can and should be used, as well as additional outreach on the early life history of the species (bit.ly/EarlyLifeAsianCarp). (Tatiana Garcia, University of Illinois)

How can we gauge the effectiveness of outreach campaigns? There is a need to get the word about Asian carp to angler groups who target rough fish and may encounter Asian carp in new locations. (Christopher Jerde, Notre Dame)

Can bait dealers and anglers identify juvenile Asian carp? There is a need to improve the outreach and education in the wholesale and retail bait trade to reduce risk of accidental transfer. (Christopher Jerde, Notre Dame)

eDNA

Environmental DNA is driven by technology, which will lead to a diverse set of future research questions related to Asian carp, other aquatic invasive species, and native species.

What things in the environment or food items could inhibit eDNA? (Duane Chapman, USGS)

There is a need for new markers, to validate those markers, develop new tools, and compare new methods to existing methods, including the use of these techniques for other species as well. (Mark Gaikowski, USGS)

Can we tell living from dead DNA? (Mark Gaikowski, USGS)

Can we use species-specific metabolites for detection? Could mass spectrometry be used to identify compounds in the environment and identify species? (Mark Gaikowski, USGS)

What are the background levels of eDNA in the natural environment for these species? There is also a need to acknowledge that eDNA water samples are not collected at random and are taken from the surface only. Is this the best methodology? Does the public understand what eDNA means? (Emy Monroe, USFWS)

GRASS AND BLACK CARP

Where are the Grass Carp? There is confirmed spawning in the Sandusky River, and we might be able to use Grass Carp to find likely spawning habitat of the other Asian carp species. (Duane Chapman, USGS)

What do we know about Grass Carp and Black Carp? (Mark Gaikowski, USGS)

Could the Grass Carp population in Great Lakes take off after 20 year lag time? (Duane Chapman, USGS)

BIOLOGY

We need to know more about the population dynamics of Asian carp. (Peter Sorensen, University of Minnesota)

What triggers movement? (Jon Amberg, USGS; Marybeth Brey, Southern Illinois University)

How many fish are needed to successfully spawn? (Duane Chapman, USGS)

Can weirs or Australian-style carp traps be used at pinch points? The life cycle could be the weak link that is used to attack Asian carp. Can temporary settling basins or similar solutions be used to collect drifting eggs from the water column? (Duane Chapman, USGS)

Where are juvenile Asian carp? (Marybeth Brey, Southern Illinois University)

How can we track smaller fish at a finer resolution? (Aaron Parker, USFWS)

Is it possible for eggs and larvae to pass from the Des Plains River to the CAWS above the barrier? There is a fence but that would not stop eggs or smaller individuals. (Doug Yeskis, USGS Illinois Water Science Center)

What predators re eating juvenile Asian carp? (Jon Amberg, USGS)

IMPACTS ON THE GREAT LAKES

What are the potential impacts on the Great Lakes? How large would they be? (Christopher Jerde, Notre Dame)

What habitats would they use in the Great Lakes? (Duane Chapman, USGS)

MANAGEMENT

What is the lag time with these species in a new environment? (Quinton Phelps, MO DOC)

How do we manage over different jurisdictions with different policies? (Quinton Phelps, MO DOC)

A workable and nimble rapid response is needed. (Duane Chapman, USGS)

There is a need a more visual way like an interactive map, to see where the investment of research dollars and work is occurring. (Christopher Jerde, Notre Dame)

What would be regulatory hurdles before new solutions, like CO2 and new poisons, could be used? (Cory Suski, University of Illinois; Mark Gaikowski and Terry Hubert, USGS)

How do we tie all this Asian carp research together? (Peter Sorensen, University of Minnesota)

INTERVIEWS

Ryan Adams, U.S. Geological Survey, Illinois Water Science Center

Jon Amberg, U.S. Geological Survey, La Crosse, WI

Marybeth Brey, Southern Illinois University (Currently U.S. Geological Survey, La Crosse, WI)

Steve Butler, Illinois Natural History Survey

Duane Chapman, U.S. Geological Survey, Columbia, MO

Matt Diana, Illinois Natural History Survey

Jim Dunkirk, U.S. Geological Survey, Illinois Water Science Center

Sam Finney, U.S. Fish and Wildlife Service, Carterville, MO

Mark Gaikowski, U.S. Geological Survey, La Crosse, WI

Tatiana Garcia, University of Illinois Urbana-Champaign (Currently U.S. Geological Survey, Illinois Water Science Center)

Terry Hubert, U.S. Geological Survey, La Crosse, WI

Ryan Jackson, U.S. Geological Survey, Illinois Water Science Center

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Emy Monroe, U.S. Fish and Wildlife Service, Onalaska, WI

Elizabeth Murphy, U.S. Geological Survey, Illinois Water Science Center

Aaron Parker, U.S. Fish and Wildlife Service, Carterville, MO (Currently Michigan Department of Environmental Quality)

Nick Phelps, University of Minnesota, Aquatic Invasive Species Research Center

Quinton Phelps, Missouri Department of Conservation

Peter Sorensen, University of Minnesota, Aquatic Invasive Species Research Center

Cory Suski, University of Illinois Urbana-Champaign

Dave Wahl, Illinois Natural History Survey

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Analysis of Education and Outreach

ABBREVIATIONS ANALYSIS CATEGORIES

The following pages are designed quick comparative reference of Asian carp prevention topics, audiences, and other information. For a full, unabbreviated version of this document, visit: go.osu.edu/asiancarpoutreach

PREVENTION TOPICS ABBREVIATIONS AND DESCRIPTIONS

(**Prevent Additional**) We can prevent additional introductions of Asian carp into Great Lakes waters.

(**Must Stop Now**) It is necessary to prevent additional introductions at this time because if breeding populations are established we will be left with no good options.

(**Control Challenges**) Control programs will be costly, possibly damaging to natives, and almost certainly ineffective at completely eradicating Asian carp.

(**Consequences**) If we do nothing we will suffer the full effects of Asian carp on Great Lakes ecosystems and economies that depend on them.

AUDIENCES

Anglers
Bait Stores
Food Markets
Stocking Entities
State Agencies
Boaters
Marinas/Harbors
General Public
Other

INFORMATION ABBREVIATIONS AND DESCRIPTIONS

(**Info Based**) Material is strictly info based; e.g. life history info, current distribution, ecology info, etc.

(**Identification**) Identification tips

(**Early Detection**) Monitoring and early detection

(**State Policy**) Conveys state policy

(**Drives to More Info**) Material attempts to drive the audience to more information; e.g. provides websites, phone number, organizations, etc.

(**Call to Action**) Material is trying to change behavior; e.g. telling the reader what they can do

(**Other Materials**)

STATE, REGIONAL (RG)	DOCUMENT	SUMMARY	PREVENTION				AUDIENCES									INFORMATION						
			Prevent Additional	Must Stop Now	Control Challenges	Consequences	Anglers	Bait Stores	Food Markets	Stocking Entities	State Agencies	Boaters	Marinas/Harbors	General Public	Other audience	Info Based	Identification	Early Detection	State Policy	Drives to More Info	Call to Action	Other IMaterials
IL	Bighead and Silver Carp Watch	Brief description of Bighead and Silver Carp with photos with tips for identification.					X					X		X		X	X				X	
IL	Bighead and Silver Carp ID Card	Two detailed photos of Bighead and Silver Carp for identification.					X					X		X		X	X					
IL	Bones of Contention (IL DNR, 2012)	Bones of Contention is an article written for those individuals interested in or curious about eating Asian carp. It provides tips, recipes and contact information for obtaining and cooking Asian carp. It is a marketing tool that may result in education of consumers.					X		X						People who eat Asian carp				A	X	X	
IL	SAH Temporary Tattoo - Clyde, the Asian Carp (IL-IN Sea Grant)	This is a giveaway that exposes kids to Asian carp and the Stop Aquatic Hitchhikers campaign in a fun way. It also serves as a bridge to educate young people about Asian carp in an in-person outreach setting.													Kids							
IL	Asian Carp Cuisine (IL-IN Sea Grant, INHS)	Asian Carp Cuisine is an outreach publication written for those individuals interested in or curious about eating Asian carp. It provides basic life history, information about the palatability of Asian carp, and details that consumption of Asian carp may reduce numbers. The overall goal of the publication is to encourage Asian carp consumption to reduce the impact of the species.					X		X						People who eat Asian carp	B			A	X	X	
IL	Fend Off Flying Fish (IL-IN Sea Grant, INHS)	This is a publication designed to counteract the potentially harmful effects of jumping Asian carp. It imparts upon boaters the importance of taking steps to be safe while boating in infested waters, and details a number of steps to take to help ensure a boat trip in Asian carp infested waters is safe.										X								X	X	
IL	Jumping Carp Video (INHS)	A video demonstrating the jumping abilities of Asian carp.					X					X			People interested in Asian carp jumping behavior					X		
IL	Bighead & Silver Carp Watch Poster (INHS)	Poster primarily utilized for identification of Bighead and Silver Carp; also includes tips on what to do to prevent the spread of these fish, and who to contact if you encounter one.					X	X			X	X	X			B	X			X	X	
IN	STOP the Invasion Brochure (IN DNR, 2013)	Brochure designed to educate readers about Asian carp and encourage participation in prevention. Contains life history information, identification tips, information about how Asian carp harm ecosystems, and how readers can help.	X				X					X				C	X		X	X	X	
IN	STOP the Invasion Poster (IN DNR, 2011)	Poster designed to educate readers about Asian carp and encourage participation in prevention. Contains identification tips, information about how jumping Asian carp can be a threat, and how readers can help stop the spread of Asian carp.	X				X					X					X		X	X	X	
IN	AIS Factsheet: Bighead Carp (IN DNR, 2011)	Factsheet detailing life history, distribution, identification, invasion history, dispersal, impacts, and management activities for Bighead Carp.	X				X		X	X	X	X				X	X			X	X	
IN	AIS Factsheet: Silver Carp (IN DNR, 2011)	Factsheet detailing life history, distribution, identification, invasion history, dispersal, impacts, and management activities for Silver Carp.	X				X		X	X	X	X			X	X	X			X	X	
IN	Asian Carp Slideshow Video (IN DNR, 2010)	This video is a photograph series detailing Asian carp jumping in and around an Indiana DNR boat in the West Fork of the White River.					X					X			X	D				X		

A: Not specifically, although since this article is about consuming Asian carp in IL, it's inferred this is legal.
B: No (but includes some life history info)
C: No (but includes some info about life history and ecology)
D: No (but mentions current distribution)

STATE, REGIONAL (RG)	DOCUMENT	SUMMARY	PREVENTION				AUDIENCES										INFORMATION						
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IN	An Asian Carp Primer Video (IN DNR, 2012)	A video interview with John Goss detailing some life history and ecology information about Asian carp, how they've moved into Indiana, and how not moving fish can help prevent new populations from establishing.	X				X					X			X		X				X	X	
IN	How to Cook Asian Carp Video (IN DNR, 2012)	A brief video detailing how to cook Asian carp using a small fryer.					X					X			X					A	X		
MI	Asian Carp Brochure & Poster (MI DNR, 2010)	Subtitle says it well: "Know the facts and learn how you can help/ Recognize carp and protect our waters from them."	X				X	X		X								X	X	X	X	X	
MI	Factsheet (MI Sea Grant, 2012)	This fact sheet includes a map of CAWS. The purpose is to inform rather than change behavior, although instructions for reporting new occurrences are included.	X				X	X	X	X	X	X	X	X			X		X		X		
MI	Factsheet (MI DNR)	Basic bulleted fact sheet. Fairly detailed information in each bullet provides basic information including recent research results, prevention actions, and notes on policy and court cases.	X				X	X	X	X	X	X	X	X			X		X	X	X		
MI	Most Unwanted Poster (MI Sea Grant)	Poster is designed to raise awareness of k-12 students. A "How you can help" section is included along with a link to ProtectYourWaters.net, but the target audience is probably responding most to the graphics and "Most Unwanted" message.													K-12 students		X		X		X		
MI	News Article: Why Grass Carp Deserve More Attention (MSU Extension, 2012)	This article describes potential negative aspects of Grass Carp in the Great Lakes basin and notes basic differences between Grass Carp and planktivorous Bighead and Silver Carp.					X	X	X	X	X	X	X	X			X				X		
MI	Bighead Carp Invasive Species Alert (MI DNR)	Factsheet detailing identification, preferred habitat, distribution, diet, and potential impacts. Contact information provided to report catches or sighting					X	X									X	X			X		
MI	Black Carp Invasive Species Alert (MI DNR)	Factsheet detailing identification, preferred habitat, distribution, diet, and potential impacts. Contact information provided to report catches or sighting					X	X									X	X			X		
MI	Grass Carp Invasive Species Alert (MI DNR)	Factsheet detailing identification, preferred habitat, distribution, diet, and potential impacts. Contact information provided to report catches or sighting					X	X									X	X			X		
MI	Silver Carp Invasive Species Alert (MI DNR)	Factsheet detailing identification, preferred habitat, distribution, diet, and potential impacts. Contact information provided to report catches or sighting					X	X									X	X			X		
MI	State of Michigan Status and Strategy for Grass Carp Management (MI DNR)	Comprehensive summary of Grass Carp management in Michigan. Summarizes the current level of understanding the biology and ecology of Grass Carp, current management options for Grass Carp in Michigan, and possible future directions of Grass Carp management in Michigan	X	X	X	X					X			X			X	X	X	X			
MI	Know the Difference: Invasive versus Common Carp (MI DNR)	Helpful identification tips for different types of carp, with a short life history summary of the different species. Briefly discusses the potential impact of invasives on the Great Lakes and provides information to report invasive specie sitings.	X	X		X	X	X				X		X				X		X	X		
MI	Video: Grass Carp in Lake Erie: A Multi-State Discovery and Research Effort (MI DNR)	Video of Michigan and Ohio DNR teams, attempting to capture Grass Carp in western Lake Erie for various research projects, e.g. assess reproduction, tagging to monitor preferred habitat. The video focuses on the multistate effort to prepare for Asian carp populations in Great Lakes.					X							X					X				

A: Not specifically, although since this article is about consuming Asian carp in IL, it's inferred this is legal.

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MI	**Video: Juvenile Asian Carp Identification (MI DNR)**	A video to assist anglers and the general public in identifying juvenile Asian carp. Juvenile Asian carp can be confused with common baitfish -- such as Gizzard Shad, Emerald Shiner, Spottail Shiner or Golden Shiner. Because bait is often transported across state lines, including from areas with breeding populations of Asian carp, it would be easy for juvenile Asian carp to make their way into the bait supply without anyone realizing it. This video showcases five characteristics viewers can use to distinguish between juvenile Asian carp (Bighead and Silver) and common baitfish. These characteristics include color, scales, eyes, mouths and keels.	X				X	X						X			X	X			X	
MI	**Video: Asian Carp Training in Illinois - Impressive Netting (MI DNR)**	Michigan DNR fisheries personnel assisted the Illinois DNR and commercial fishermen to remove Asian carp from a section of the Illinois River.					X				X			X								
MI	**Video: Asian Carp Training - Illinois River (MI DNR, 2015)**	Michigan DNR fisheries personnel assisted the Illinois DNR and commercial fishermen to remove Asian carp from a section of the Illinois River.					X				X			X								
NY	**Article: "Asian Carp - Threats to the Lower Great Lakes and St. Lawrence River?" (NY Sea Grant, 2011)**	Discusses the 4 species of Asian carp that are of greatest concern to the Great Lakes, including identication tips and their ecological threats to the Great Lakes. Includes a short summary of their history in the United States, and preferred habitats and life history triaits. Highlights the electric barriers along the Chicago canal, and efforts to assess where in the Great Lakes they may already be. Mentions what you should do if you catch an Asian carp, and includes a few notes regarding human consumption of Asian carp.	X				X							X			X	X	X	X		
OH	**Poster: Bighead and Silver Carp in the Ohio River Basin (ODNR)**	This is a poster geared towards any user of the Ohio River Basin waterways. It teaches how to identify Bighead and Silver Carps, complete with pictures. It then provides procedural steps to take if you catch and identify one, including taking a picture of the whole fish, and sending that with location information to the ODNR DOW via their website, or phone number.												X	Users of Ohio River basin waterways	X	X		X	X	X	
OH	**Poster: It is illegal to use Bighead or Silver Carp as live bait in Ohio (ODNR)**	This is a poster geared towards any fisher or bait dealer in the state, but particularly those that use Ohio River basin waters. It teaches how to identify juvenile Bighead and Silver Carps in contrast to native Gizzard Shad and Skipjack Herring, complete with pictures. It makes readers aware that it is illegal to use Asian carps as bait and also to never release live fish from one water body to another. Guides readers to ODNR website and phone number for more information.	X				X	X							Especially people in Ohio River basin	X	X		X	X	X	
OH	**Poster: ORFMT Asian Carp Flier (Ohio River Management Team)**	This is actually two posters, both very similar to the ODNR posters already summarized. It uses the same photos and designs, but includes some more text. It also urges readers to contact 877-STOP-ANS and asiancarp.us instead of the Ohio DNR, and has many more partner logos listed. Poster 1- This is a poster geared towards any user of the Ohio River Basin waterways. It teaches how to identify Bighead and Silver Carps, complete with pictures. It then provides procedural steps to take if you catch and identify one, including taking a picture of the whole fish, and sending that with location information to the authorities via their website, or phone number. Poster 2- This is a poster geared towards any fisher or bait dealer in the Ohio River basin. It teaches how to identify juvenile Bighead and Silver Carps in contrast to native Gizzard Shad and Skipjack Herring, complete with pictures. It makes readers aware that it is illegal to use Asian carps as bait and also to never release live fish from one water body to another. Guides readers to authority's website and phone number for more information.	X				X	X							Especially people in Ohio River basin	X	X		X	X	X	
PA	**Asian Carp Factsheet (PA Sea Grant)**	This is a 2-page factsheet that gives general information on Asian carp including identification tips, life history information, distribution, impacts, control information, and tips for how to prevent the spread of Asian carp. Also includes Pennsylvania regulations regarding movement/transport/possession of Asian carp in the Commonwealth.	X											X		X	X		X		X	

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WI	**Brochure: Asian carp: Keep invasive species out of Wisconsin (WI DNR)**	Describes that Asian carp are, with large pictures and tips to ID. Describes potential impacts to native ecosystems and how individuals can prevent the invasion of Asian carp (and other species). Final 2 page insert describes the specific actions that WI DNR is taking.	X				X	X						X		E	X	X	X	X	X	Also shows juvenile Silver and Bighead Carp next to a gizzard shad.
WI	**Informational page: Asian carp control efforts (WI DNR, 2013)**	This website provides general information on Asian carp to WI DNR visitors. Topics include current distribution in WI, what citizens can do, and what the DNR is doing. Site also contains information on current news on Asian carp from the WI DNR, pictures and characteristics to ID Asian carp, a FAQ, contacts, and resources.	X			X	X								Users of DNR website	F	X	X	X	X	X	G
WI	**Poster: Asian carp in WI waters (WI DNR, 2012)**	A map showing the locations of Silver Carp and Bighead Carp in Wisconsin and the year they were captured. Also shows the major barriers to upstream migration in the larger WI rivers that are connected to the Mississippi River.												X		X		H				A one page map showing the current distribution (2012) of Silver Carp and Bighead Carp in WI.
LA	**Louisiana Sea Grant. Article. 2010. "Louisiana Sea Grant and LSU AgCenter Turn Problem Fish into Nutritious Dish for Haitians in Need"**	LSU AgCentre has successfully produced canned Asian carp that is pleasing the Haitian palate, a community that has inadequate access to nutrious food options. This food option "could create jobs and feed people."												X								
LA	**Louisiana State University AgCenter & Louisiana Sea Grant. Factsheet. "Bighead Carp and Silver Carp"**	Brief identification description and life history summary, with links to maps of US distributions of Bighead and Silver Carp.					X							X		X	X			X		
LA	**LSU AgCenter article: Unwelcome Guest for Dinner - Asian Carp**	Article is mostly a description of the biology and history of Asian carp issues in Mississippi River. At the end is also describes the commercial fishery in Louisiana and potential for Asian carp as a food source.					X									I						
LA	**Louisiana Department of Wildlife and Fisheries. 2010. "Asian carp cause problems for waterways, boaters."**	Brief news release, summary of Asian carp concerns in Louisana, e.g. large size as a threat to boaters and their equipment, out competing other local fish. "Hope to create a demand for the meat, to create a commercial and recreational fishing industry for Asian carp."					X		X					X								

E: No (includes info on life history relative to potential threats to native species)

F: No (includes info on current distribution, impacts to native species, and how people can help)

G: This is an informative reference with useful pictures of carp and tips to help identify them. Similar to the Wisconsin DNR. Brochure. "Asian carp: Keep invasive species out of Wisconsin". There is a long list of contacts at the DNR, but also at other agencies. The news feed is nice, but only posts WI DNR news on Asian carp, so most recent is over a month old and interval between stories is sometimes large.

H: No (includes map of location of Silver/Bighead Carp captures) month old and interval between stories is sometimes large.

I: No (includes some info though)

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LA	**Louisiana State University AgCenter. 2010. "Flying Fish, Great Dish Part 1- Introduction & Removing Filets."**	A brief summary of the Asian carp establishment in the Mississippi and Missouri river region, with many video samples of Asian carp netting in the field. With these established populations, one could use them as an appealing food source, more appealing than common carp. "Asian carp are also an excellent fish to eat- offering large, low-fat, nutritious filets." The video then summarizes the anatomy of Asian carp as you prepare an Asian carp for fileting.					X		X					X									
LA	**Louisiana State University AgCenter. 2010. "Flying Fish, Great Dish Part 2- Making 'Flying Carp Wings.'"**	This video teaches you how to make Flying Carp Wings - continued instructions from Part 1. The segment is the second in a series of three that teach you how to turn flying fish into an appealing dish.					X		X					X									
LA	**Louisiana State University AgCenter. 2010. "Flying Fish, Great Dish Part 3-Deboning Filets & Closing Credits."**	Continued instructions from Part 1 and Part 2, this video goes into more detail regarding deboning Asian carp filets.					X		X					X									
MO	**Article: "Carp Lemonade" (MO Dept of Conservation & USGS, 2010)**	This article briefly covers the how, why, and what of Asian carp invasion. Most of the text is spent on describing ways to catch, clean and cook Silver and Bighead Carp. Very informative for people who might have access to Asian carp but don't know the best ways to clean/cook them. Development of a market for Asian carp is a first step for making a self-sustaining Asian carp fishery.					X					X		X		X					X		
MO	**Missouri U.S. Geological Survey. "Duane Chapman on Cooking Asian Carp."**	Short video summarizing the many appealing ways to cook Asian carp, the key being proper fileting to easily remove all the bones. Website noted at the end for more information on Asian carp.					X							X							X	X	
MS	**Mississippi Interstate Cooperative Resource Association. "Report New Sightings of Bighead and Silver Carp."**	Public announcement: report sighting of Bighead and Silver Carp, with photos and identificiation tips of both adult and juvenile fish, as well as photos of similar native fish species. Includes tips to prevent the spread of Asian carp.					X	X				X					X		X	X	X	
MS	**St. Croix River Association and Mississippi River Fund. 2012. "There is still time to protect your national parks."**	1 page announcement/flyer. Alert to identify and report Asian carp sightings - with photos and ID tips. Advice to drain boats and not move bait fish, minimize lock use, and report sightings.					X										X			X	X	
MS	**St. Croix River Association and Mississippi River Fund. "Identifying Bighead and Silver Carp Watch card."**	Small printable pdf (designed to fit in a wallet or pocket), with photo and identificiation tips of Bighead and Silver Carp, brief summary of concerns and what you can do to prevent the spread of these fish. Contact information provided for more information and to report sightings and catches.					X	X				X		X			X	X		X	X	
TN	**Tennessee Wildlife Resources Agency & Wildlife Forever. Poster "Asian Carp in Tennessee"**	Summary of the 4 Asian carp species of concern (US invasion history, habitat preferences, current threats to local ecosystems), and where in Tennesse they currently reside (with map). Discussions current management practices in Tennessee and potential future management and control methods.									X			X		X			X			

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TN	**Tennessee Wildlife Resources Agency, U.S. Fish & Wildlife Service and Bill Dance. 2006. "Nuisance Fish."**	Focuses on the issues involving the exotic Asian carp. It is a six-minute video message that works well in school presentations, recreation shows, natural resource group meetings, and anyone concerned about aquatic resources on the Mississippi River Watershed and Great Lakes. Stresses that anglers need to be careful to not transfer this fish as bait.					X					X		X			X				X	
RG	**Asian Carp Regional Coordinating Committee. 2012. "FY 2012 Asian carp control strategy framework"**	"This document "lays out the strategy and presents the proposed action items....to create a sustainable Asian carp control program and to implement actions for protecting and maintaining the integrity and safety of the Great Lakes ecosystem from an Asian carp invasion via all viable pathways." A strategy to deal with Asian carp is developed using the best science available. Report is detailed and describes the threats of Asian carp, a strategic approach to management, current efforts underway, agency roles, stakeholder participation, and monitoring and control outside the Great Lakes. Lots of information here. Describes action items that are currently being investigated (Appx B)	X	X	X						X			X	Researchers	J		X	K	X		
RG	**Asian Carp Regional Coordinating Committee. 2010. "What to Do If You Think You Have Found an Asian Carp"**	2-page document with identification tipys and photos of Bighead, Silver, and Black Carp. Contatct information to report sightings for Natural Resource offices in Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York					X							X			X			X	X	
RG	**Columbia Environmental Research Center U.S. Geological Survey. 2003. "Bighead and Silver Carp in the Mississippi and Missouri Rivers."**	Summary of the life history and threat to local regions by Asian carp. Includes summary of recent research efforts to understand preferred habitats, as well as areas of future research. Article summary as well as 1-page bulletpoint handout.									X			X		X				X		
RG	**Great Lakes Fishery Commission. Poster. "Asian carp: keep them out of the Great Lakes"**	Poster developed by Great Lakes Fishery Commission – tag line message "Asian carp – keep them out of the Great Lakes. Has a few bullets about why Asian carp are a problem, and what is being done. Includes map of Lake Michigan/Chicago area to show how close Asian carp are to Great Lakes.	X				X							X						X		
RG	**Great Lakes Fishery Commission. "Asian carp: The war isn't over."**	This article summarizes current efforts to keep Asian carp out of Lake Michigan and discusses the impacts that could happen if Asian carp were to get into the Great Lakes; for example, damage to the $7 billion dollar Great Lakes fishery. The article urges that we need to do more. Also discusses the Chicago Waterway Study and the idea of separating the Great Lakes from the Mississippi River to prevent the movement of species between the two basins.	X	X										X	Science professionals				X			Update on importance of Asian carp work and what studies are being done, and why the studies are important.
RG	**Great Lakes Aquatic Nuisance Species Information System, National Oceanic and Atmospheric Administration & Great Lakes Restoration. 2012.**	Detailed report of Silver Carp, including identification, native range, ecology, means of introduction to the US, further potential expansion to the Great Lakes and the potential impacts, as well as management practices towards population control.	X								X				Science professionals	X		X	X	X		

J: No (gives background info and current research)
K: No (discusses federal policy/Lacey Act)

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RG	**International Joint Commission of the United States and Canada. Letter to Legislators. 2009.**	Letter to governement officials of Illinois uging for agency collaboration across states and nations, as well as fiscal support of those agencies, and work to cut through administrative and bureaucratic obstacles in Illinois agencies to prevent Asian carp from entereing the Great lakes.	X	X							X				Government officials							
RG	**Midwest Fish Habitat Partnerships. Video. "Babe Winkelman on the importance of fish habitat."**	Video: "The loss of fish habitat is the biggest reason fishing isn't nearly what it once was." Habitat education, conservation, and restoration are the best answers to improve fish populations. Visit their webiste - **www.midwestfishhabitats.org** - to learn more about the work done by various agencies to improve natural fish habitats and populations.					X							X							X	X	
RG	**U.S. Geological Survey. 2012. "Asian Carp."**	Brief summary of establisment and threat of Asian carp in the US. Notes potential size and a few examples of their range in the US. Currently conducting assessment to have these species listed as injurious wildlife in the Lacey Act, which would prohibit by law importation and transportation.									X						X		X			
RG	**U.S. Geological Survey. Factsheet. "USGS Science and Technology Help Managers Battle Invading Asian Carp". 2016.**	Abstract of full report (linked in document). Report discusses USGS research on Asian carp, with the goal of preventing establishment in the Great Lakes. Managers can use the information, tools, and strategies for early detection of Asian carp and to control them when their presence is first evident. 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.	X	X		X					X				Science professionals			X		X		
RG	**U.S. Geological Survey. Nonindigenous Aquatic Species Database. Central repository for spatially referenced biogeographic accounts of introduced aquatic species.**	Database: this website has been established as a central repository for spatially referenced biogeographic accounts of introduced aquatic species. The program provides scientific reports, online/realtime queries, spatial data sets, distribution maps, and general information. The data are made available for use by biologists, interagency groups, and the general public. The geographical coverage is the United States.									X				Science professionals	X	X	X		X		X
RG	**"Recommendations for Removal of Asian Carp Carcasses on Vessel" (U.S. Coast Guard, 2012)**	BMP for keeping Asian carp upstream of the electric barrier, which could result in eDNA hits from dead fish transported via vessels. Bilge water and ballast cannot be transported across the barrier. The transported fish could also be alive and get back into the water (evidence of live fishing being trucked multiple days and still being alive = not farfetched).										X	X		Users of Dresden Island and Brandon Road lock and dams.			X	X	X	X	Method designed to not delay vessel passage through Lock.
RG	**U.S. Coast Guard. Brochure. 2012. "Waterway Notice"**	Brochure developed by USCG for boaters/ship captains outlining safety concerns/actions and ballast restrictions to take when traveling through the electrical barriers in the Chicago Sanitary and Ship Canal.										X			People going through electrical barriers at Chicago Sanitary and Ship Canal				X			Gives guidance on safety concerns and safety steps to take when going through electrical barriers.
RG	**U.S. Geological Survey. "Activities in Controlling and Monitoring Asian Carp Movement, 2010"**	Detailed article summarizing the concern of Asian carp passage through the Chicago Area Waterway System, current methods of prevention, as well as current research to assess regions for early detection of fish, eggs, and larvae.	X								X				Science professionals			X				

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RG	U.S. Fish and Wildlife Services. Video. 2012. "How to identify Asian carp"	Video. Many images of Asian carp, includes identification tips, as well as the threats to local ecosystems as well as recreational fishing. Both Bighead and Silver Carp have been labeled as injurious, making it illegal to transport Asian carp.	X				X					X		X			X		X		X	
RG	U.S. Fish and Wildlife Services and Mississippi River Basin Panel. 2004. "Asian Carp."	Summary of the 4 Asian carp species of concern (basic ID and life history summary, US invasion history, habitat preferences, current threats to local ecosystems), with US distribution maps. Includes a paragraph of "what you can do" to be aware of area laws and regulations, and to utilize care in regards to baitfish.					X							X		X	X		X	X	X	
RG	U.S. Fish and Wildlife Services and Mississippi River Basin Panel. 2004. "Asian Carp Key to Identification."	Summary of the 4 Asian carp species of concern with more detailed identification tips, with US distribution maps. Includes a paragraph of "what you can do" to be aware of area laws and regulations, and to utilize care in regards to baitfish.					X							X			X	X	X	X	X	
RG	U.S. Fish & Wildlife Services. 2002. "Black Carp."	2 page factsheet summarizing Black Carp: Identification, native region, invasion history, impacts on US aquatic habitats, and current management practices					X				X			X		X	X	X	X	X	X	
RG	U.S. Fish & Wildlife Services. 2004. "Asian Carp – Aquatic Invasive Species."	Summary of Asian carp in the Great Lakes region, reviewing the pathway and introdution to the US, biology and ecology of the fish, distribution, and ecological risks and impacts, especially to the Great Lakes region.	X	X		X	X				X			X		X		X	X	X		
RG	U.S. Fish and Wildlife Service. 2005. "Proceedings of the Asian Carp Working Group Meeting, May 24, 2004."	An extensive summary of the Asian carp working group, with representation from several Federal agencies, eleven state natural resource management agencies, as well a Native American, and Canadian representatives. Many constituencies were represented, including aquaculture, Great Lakes fisheries, and NGO's. Their challenge was to come together to create a comprehensive, integrated anagement and control plan for Asian carp.	X	X	X	X					X				Science professionals	X		X	X			
RG	U.S. Army Corps of Engineers. Brochure. 2012. "Asian Carp and Aquatic Nuisance Species"	Brochure summarizing the threats of Asian carp to the US, as well as current management and prevention efforts.	X			X	X							X				X		X		
RG	U.S. Army Corps of Engineers. Brochure. 2012. "GLMRIS: Great Lakes and Mississippi River Interbasin Study"	Brochure summary of GLMRIS. Specific tasks of this research study include: identifying aquatic pathways that may exist between the Great Lakes and Mississippi River basins, Inventory current and future potential aquatic nuisance species, Analyze possible nuisance species controls to prevent transfers, to include hydrologic separation of the basins, Recommend a plan to prevent nuisance species transfer between the basins.	X							X					Science professionals			X	X			
RG	Wildlife Forever. 2011. "Silent Invaders Episode 3: Asian Carp."	Wildlife Forever teams up with the North American Fishing Club and other partners to produce our first television show: Silent Invaders. A quick moving information series on invasive species and what you can do to help protect you favorite waters. This is episode 3 covering the destruction of fisheries by Asian carp. Discusses current areas threatened, current management practices to prevent movement into the Great Lakes, like electric barriers, as well as options for recreation and food harvest in US areas where Asian carp are currently established	X				X					X		X								

STATE, REGIONAL (RG)	DOCUMENT	SUMMARY	PREVENTION				AUDIENCES									INFORMATION						
			Prevent Additional	Must Stop Now	Control Challenges	Consequences	Anglers	Bait Stores	Food Markets	Stocking Entities	State Agencies	Boaters	Marinas/Harbors	General Public	Other audience	Info Based	Identification	Early Detection	State Policy	Drives to More Info	Call to Action	Other IMaterials
RG	**Canada Fisheries and Oceans. Factsheet. 2012. "Ecological Risk of Bighead and Silver Carps"**	Visually engaging and concise synopsis of DFO risk assessment. Clearly conveys some basic aspects of invasion biology that are often misunderstood (e.g., introduction vs. establishment). Clearly demonstrates that Asian carp are a high risk in terms of ability to survive, reproduce, and negatively impact Great Lakes. Also notes CAWS as riskiest pathway but does not give advice on what people can do to prevent introduction.	L	X M										X	Great Lakes stake-holders	X						
RG	**Ontario Ministry of Natural Resources. Factsheet. 2011. "Asian carps-Threatening Ontario's native fishes"**	Comprehensive FS; threats, impacts, what to look for, where to look, what to do, how to do, who to call; also compares to native looka-likes	X	X	X		X					X		X	Water skiers, Importers	X	X	X	X	X	X	
RG	**Ontario Ministry of Natural Resources and Ontario Federation of Anglers and Hunters. Informational page. "Asian Carps"**	Comprehensive IP; threats, impacts, what to look for, where to look, what to do, how to do, who to call; also compares to native looka-likes	X	X	X		X					X		X	Water skiers, Importers	X	X	X	X	X	X	

L: No (but CAWS is clearly identified as the riskiest pathway for invasion)
M: Need for prevention now is implied but not explicitly spelled out

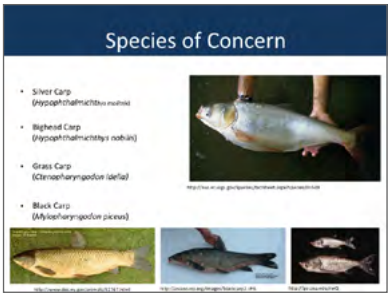
Asian Carp PowerPoint and Presenter Notes

The following pages feature slide thumbnails and presenter notes for an Asian carp PowerPoint presentation. Download at: **go.osu.edu/asiancarpPP**

SLIDE	PRESENTER NOTES

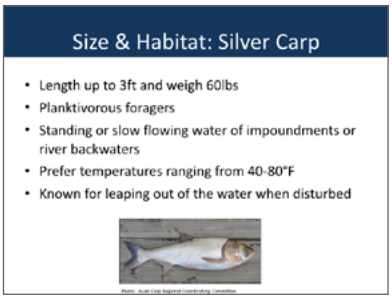
1

Download this PowerPoint at: go.osu.edu/asiancarpPP



2

a) Specific species of concern:
   i) Silver Carp (SC - *Hypophthalmichthys molitrix*)
   ii) Bighead Carp (BHC - *Hypophthalmichthys nobilis*)
   iii) Grass Carp (GC - *Ctenopharyngodon idella*)
   iv) Black Carp (BC - *Mylopharyngodon piceus*)



3

SC – Can grow to lengths of 1m and weights of 27kg (Lin 1991; Pflieger 1997)

Planktivorous, water column foragers (Kolar et al. 2007)

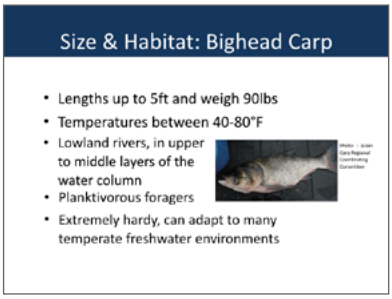
Prefer standing or slow flowing water of impoundments or river backwaters ranging in temperature from 6-28C (Fuller et al. 1999)

Very active, schooling species well known for their habit of leaping out of the water when disturbed (Mukhamedova 1977; Kolar et al. 2007)

Adults in the lower Missouri River usually use low velocity areas behind wing dikes, especially areas > 3 m deep (unpublished data, Duane Chapman, USGS)

Thousands of individuals have also been observed in off-channel areas of the Mississippi River (unpublished data, Nate Caswell, USFWS)

Indications that can live in slightly brackish water (FAO 1972; Kolar et al. 2007)



4

BHC – 1.5m and weights of 40kg (Laird and Page 1996)

Planktivorous, water column foragers

Lowland rivers, preferring temperatures between 4-26C (Kolar et al. 2007)

School and occupy the upper to middle layers of the water column (Kolar et al. 2007)

Extremely hardy, can adapt to many temperate freshwater environments (Kolar et al. 2007)

Reported in low-velocity and off-channel habitats in the Missouri, Mississippi, Wabash, and lower Ohio rivers (Kolar et al. 2007)

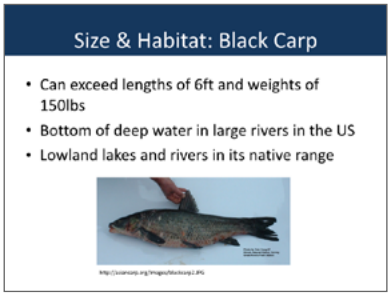
SLIDE	PRESENTER NOTES

5

Size and habitat

(i) GC – Can grow to lengths of 1.6m and weights of 37kg (Pflieger 1997; Bowman 1998)

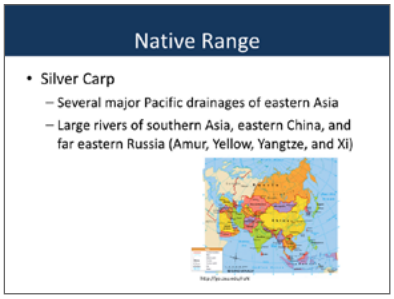
1. Shallow quiet waters, can tolerate freezing waters.
2. Most commonly reported to inhabit lower and middle reaches of rivers. (Froese and Pauly 2001)
3. Prefer large, slow flowing water bodies with available vegetation (Froese and Pauly 2001)
4. Can tolerate water temperatures between 0-38°C, but prefer temperatures of 10-26°C. (Froese and Pauly 2001)



6

(ii) BC – Can exceed 1.8m and 70kg (Nico et al. 2005)

1. Found along bottom of deep water in large rivers (hard to sample because so deep)
2. Throughout its native range the Black Carp inhabit lowland lakes and rivers (Li and Fang 1990)



7

Silver Carp are native to several major Pacific drainages in eastern Asia (Fuller et al. 1999). They are endemic to the large rivers of southern Asia, eastern China, and far eastern Russia, including the Amur River, Yellow River, Yangtze River, and Xi River (Kolar et al 2005).

8

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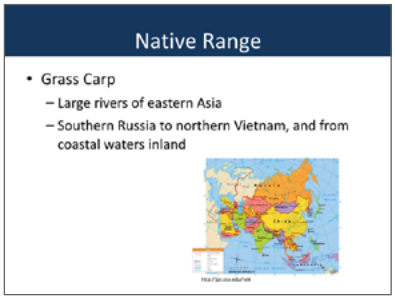

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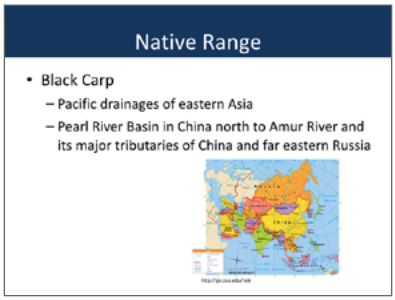
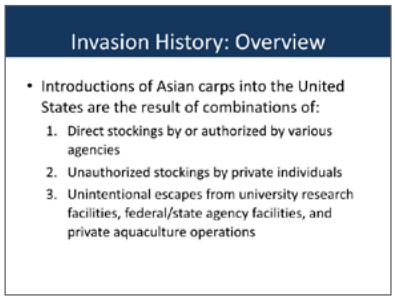


10

Black Carp native to the Pacific drainages of eastern Asia between 22 and 51°N latitudes. Its range extends from the Pearl River Basin in China north to the Amur River and its major tributaries of China and far eastern Russia, including possibly the Red River of northern Viet Nam (Frimodt 1995; Nico et al. 2005)



11

Pathway to US: How did they get here - "invasion history"

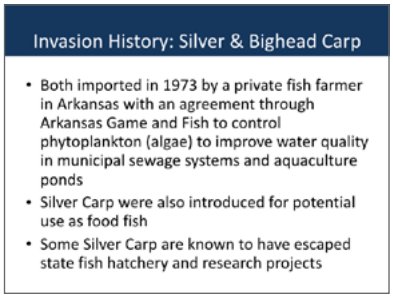
a) General: Introductions of Asian carps into waters of the United States are the result of combinations of: (Nico et al. 2005)

   (1) Direct stockings by or authorized by various agencies (Nico et al. 2005)

   (2) Unauthorized stockings by private individuals (Nico et al. 2005)

   (3) Unintentional escapes from university research facilities, federal and state agency facilities, and private aquaculture operations (Nico et al. 2005)

b) Bighead, Grass, and Silver Carps have all established reproducing populations in the United States (Nico et al. 2005)



12

(1) SC – Imported into US in 1973 under an agreement of maintenance between private fish farmer and Arkansas Game and Fish; control of phytoplankton. Is food fish. Some known to have escaped from state fish hatchery and research projects looking at their use in municipal sewage systems

Silver Carp were first brought into the United States in 1973 by a private fish farmer in Arkansas (Freeze and Henderson 1982) as a potential biological control agent to improve water quality in municipal sewage treatment lagoons and aquaculture ponds and as a food fish (Froese and Pauly 2001)

(2) BHC – As with "SC", Imported into US in 1973 under an agreement of maintenance between private fish farmer and Arkansas Game and Fish

Bighead Carp were first imported into the United States in 1973 by a private fish farmer in Arkansas (personal communication, Andrew Mitchell, USDA) as a potential biological control agent to improve water quality and increase fish production in culture ponds (Nico and Fuller 2005).

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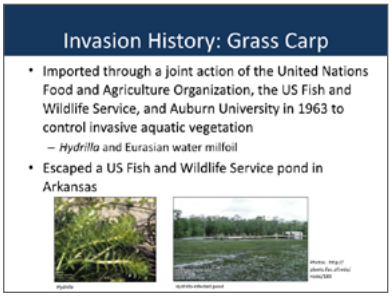
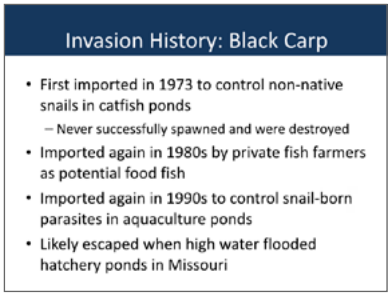
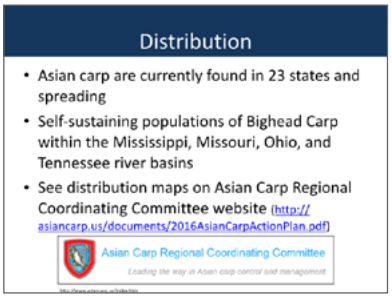
 13	(3) GC – Imported by US Fish and Wildlife Services in 1963 for biological control of aquatic vegetation; help with invasive species such as Hydrilla and Eurasian water milfoil. Escaped US Fish and Wildlife Services Fish Farming Experimental Station in Arkansas Grass Carp were brought into the United States in 1963 through a joint action of the United Nations Food and Agriculture Organization, the USFWS, and Auburn University to evaluate their use as a biological control for aquatic vegetation (Avault 1965; Stevenson 1964; Pflieger 1978; Leslie et al. 1996; Mitchell and Kelly 2006)
 14	(4) BC – Imported into US in 1973 under an agreement of maintenance between private fish farmer and Arkansas Game and Fish; biological control agent for non-native snails in catfish ponds (If sterile can be used to control zebra mussels) Black Carp were first imported into the United States in 1973 by a private fish farmer in Arkansas as part of a "mixed shipment of Chinese carps." These initial specimens were trusted into the possession of the Arkansas Game and Fish Commission for evaluation, were never successfully spawned, and were eventually destroyed (personal communication, Mike Freeze, Keo Fish Farm). Black Carp were imported into the United States on several occasions during the 1980's by private fish farmers as a potential food fish and again during the 1990s as a potential biological control for snail-borne parasites in aquaculture ponds (personal communication, Andrew Mitchell, USDA)
 15	Current Spread/distribution (will be updated as new information is reported) i) Today, Asian carp live in 23 states; their population numbers are increasing exponentially Bighead Carp have now been recorded from within or along the borders of at least 23 states(Figure 2.1.2) and are self-sustaining within the Mississippi, Missouri, Ohio, and Tennessee river basins (Kolar et al. 2007; Nico and Fuller 2005; Schofield et al. 2005). ii) see distribution maps on ACRCC website (**www.asiancarp.us/documents/ACDistribution.pdf**) and within "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States"
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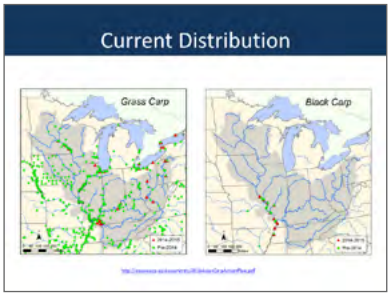

17

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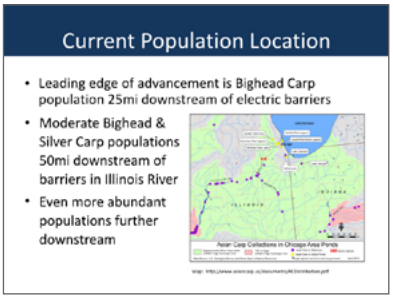
ii) see distribution maps on ACRCC website (**www.asiancarp.us/documents/ACDistribution.pdf**) and within "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States"

18

a) Some states prohibit or restrict the possession or use of certain species of Asian carp

b) Spread and dispersal pathways include the transport and release of baitfishes caught in the wild; stocking Asian carps in private or public waters for biological control; the production, live transport, and live sales of Asian carps in seafood markets; live transport and intentional spread of Asian carps by commercial fishers; movement of Asian carps in ballast waters and live wells; and intentional releases of Asian carps by consumers, hobbyists, and animal rights activists (Higbee and Glassner-Shwayder 2004; Kolar et al. 2007)



19

a) Current population location.....always looking for most current information

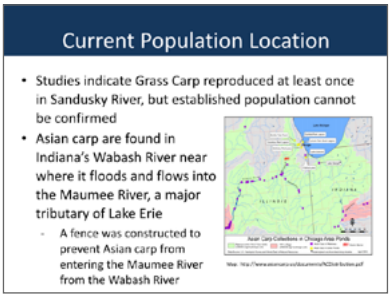
i) Leading edge of advancement is represented by a small population of Bighead Carp in the Dresden Island Pool, about 25 miles downstream of the dispersal barriers

(1) Moderately populations of BHC and SC in Marseilles Pool of the Illinois River (approximately 50 miles downstream of the dispersal barriers)

(2) There is an abundant population farther downstream of the Marseilles Pool

(3) Reproduction has not been documented in waters upstream of Marseilles Lock and Dam.

ii) Videos show fish swimming through barrier (February, 2014)



20

b) Study shows Grass Carp reproduced at least once in the Sandusky River, but it cannot confirm an established population. (29 October, 2013)

(1) Four fertile Grass Carp, discovered in the Sandusky River, were found to have been bred and born in those waters, and not been stocked or transported from elsewhere.

c) Asian carp are found in Indiana's Wabash River, a few miles from where the Wabash often floods and flows into the Maumee River, a major tributary of Lake Erie (July 2010)

(1) 1,200-foot-long, 8 feet high fence designed to prevent adult carp from using Eagle Creek Marsh to swim from the Wabash River system into the Maumee River and then onto Lake Erie during floods (October 2010)

(2) A 13-mile concrete and steel mesh fence that splits the narrow divide between the Des Plaines River and the Chicago Sanitary and Ship Canal was also completed (October 2010)

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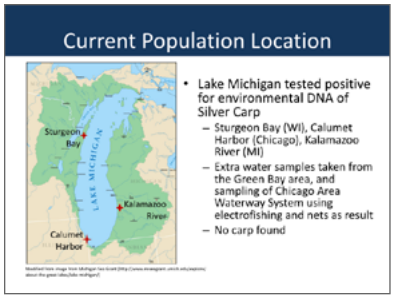


21

d) Water taken from Lake Michigan's Sturgeon Bay in Wisconsin in May of 2013 tested positive for DNA from Silver Carp (detected near Potawatomi State Park, where Sturgeon Bay opens to the larger Green Bay)

(1) This was second positive DNA hit for the Asian carp detected in Lake Michigan. The first positive hit from water taken in 2010 in Calumet Harbor, outside of Chicago.

(2) The May testing included 50 water samples taken from the Green Bay area; they were among 282 from other areas along Lake Michigan

(3) Wisconsin DNR and the U.S. Fish and Wildlife Service will take more samples from the area to determine whether the positive hit was a fluke or something worse.

e) In 2012, over 100,000 fish were netted and identified with no Asian carp being found between the electric barriers in the Chicago Sanitary and Ship Canal and Lake Michigan (CSSC).

(1) In 2012 three response actions were triggered by positive eDNA detections in the Chicago Area Waterway System (two additional actions implemented as a precautionary measure to eDNA presence)

(2) These intense sampling events totaled more than 1,600 hours of surveillance, over 27 miles of the Chicago Area Waterway System (CAWS), using 18.4 miles of gill/trammel nets and 59 hours of electrofishing

(3) Above efforts resulted in no Bighead or Silver Carp being seen or captured.

f) eDNA "triggered" events were in addition to the over 7,500 hours of sampling by ACRCC crews in the CAWS in 2012 with no Bighead or Silver Carp seen or captured above the electric barriers.

g) Bighead Carp was caught in Lake Calumet, 6 miles away from Lake Michigan (June 2010)

(1) First physical specimen that has been found in the Chicago Area Waterway System above the U.S. Army Corps of Engineer's Electric Barrier System

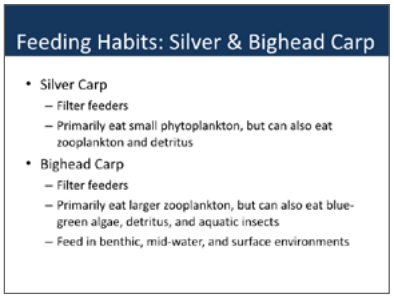
h) Poisoning conducted into two miles of the Little Calumet River below the O'Brien lock and dam (May 2010)

(1) Purpose to determine if Asian carp exist in that location where positive eDNA samples taken. No Asian carp

i) Electric barrier shut down for maintenance.

(1) To prevent Asian carp from entering lake while barrier off, fisheries managers rotenone a 5.7 mile portion of the canal

(2) Large scale fish kill results in one Asian carp



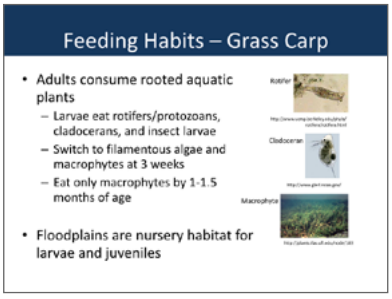
22

a) SC – filter feeder(phyto and zooplankton) ; prefer phytoplankton of smaller size but do not need to be selective

They feed primarily on phytoplankton, but also feed on zooplankton, invertebrates, detritus, and bacteria, especially when phytoplankton abundance is low (Burke et al. 1986; Kolar et al. 2007)

b) BHC – filter feeder(phyto and zooplankton) ; prefer zooplankton of larger size but do not need to be selective

The Bighead Carp feeds in benthic, mid-water, and surface environments; feeding primarily on zooplankton, but also consuming large quantities of blue-green algae, aquatic insects (adults and larvae), and detritus (Robison and Buchanan 1988)



23

Known feeding behaviors/requirements: varied

i) GC – aquatic plants, rooted

(1) Floodplains associated with rising water levels provide nursery habitat areas for larvae and juvenile forms (Fedorenko and Fraser 1978; Opuszynski and Shireman 1995)

(2) Larval Grass Carp initially feed on rotifers and protozoans, switching to larger cladocerans and insect larvae at 11-15 days post-hatch (Fedorenko and Fraser 1978; Opuszynski and Shireman 1995)

(3) Three weeks post-hatch, Grass Carp begin feeding on filamentous algae and macrophytes (Opuszynski and Shireman 1995)

(4) By the age of 1 to 1.5 months Grass Carp feed exclusively on macrophytes (Opuszynski and Shireman 1995)

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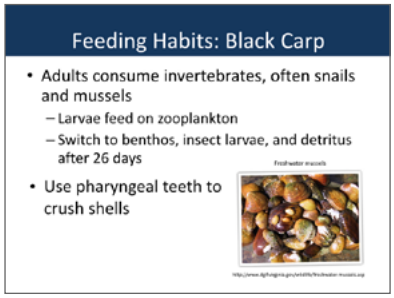
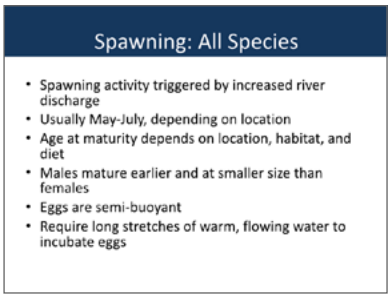
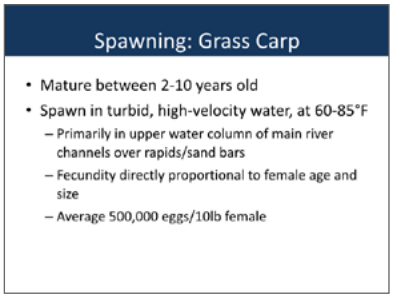
 24	ii) BC – invertebrates, primarily snails and mussels Recently-hatched Black Carp fry feed primarily on zooplankton. At 26+ days after hatching (3.1-33 cm), the pharyngeal teeth have fully formed and the fish begin feeding on a larger variety of benthos, insect larvae, and organic detritus (Liu et al. 1990; Lin 1991). Adult Black Carp feed primarily on mollusks, using their molar like pharyngeal teeth to crush the shells. The species of mollusks consumed varies with geography, fish size, and mouth gape, but usually include gastropods and bivalves (Nico et al. 2005)
 25	i) Know spawning behaviors/requirements 1) BHC, SC, and GC (and maybe BC too?) – Spawning activity is brought on by an increase in river discharge. While of course there will be regional variation throughout the US, this typically occurs in May-July (Deters, Chapman, and McElroy 2012).
 26	ii) GC – Grass Carp grow rapidly before the onset of maturity, reaching 1kg by age one and growing 2-3kg per year in temperate climates and 4.5 kg/year in tropical climates (Shireman and Smith 1983) (1) Age at maturity ranges from 2-10 years (50-86 cm) and is largely a function of water temperature and diet (Cudmore and Mandrak 2004) (2) Males generally mature one year earlier than females. Spawning activity is associated with high spring flows, and spawning areas have high water velocity, turbid water, and a temperature in the range of 15-30°C (Cudmore and Mandrak 2004) (3) Spawn primarily in the main river channel in the upper part of the water column over rapids or sand bars during times of turbulent water currents ranging from 0.6 to 1.5 m/s. (Shireman and Smith 1983) (4) Fecundity is directly proportional to length, weight, and age, averaging 500,000 eggs for a 5 kg female (Shireman and Smith 1983; Chilton and Muoneke 1992) (5) Eggs are non-adhesive and semi-buoyant, requiring flowing water for incubation. (Cudmore and Mandrak 2004) Eggs can become dispersed widely from the spawning site and have reportedly traveled downstream as far as 180km (Fedorenko and Fraiser 1978) (6) Successful reproduction requires long stretches of warm, flowing water for egg incubation and suitable backwater habitats for larval development (Verigin et al. 1978) (a) Length needed is being revised by current research projects

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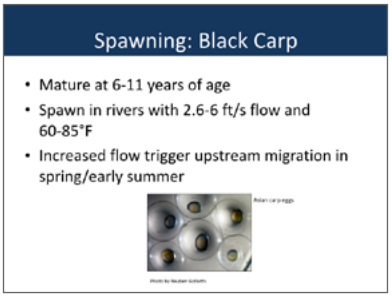


iii) BC – Black Carp mature from 6-11 years, depending on latitude, diet, and habitat (Lin 1991; Nico and Williams 1996)

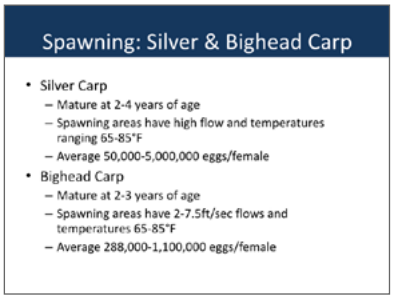
(1) Males typically mature a year earlier than females (Lin 1991; Nico and Williams 1996)

(2) Females average 1m and 15kg at maturity while males average 88cm and 10kg (Lin 1991; Nico and Williams 1996).

(3) Spawning occurs in rivers with water velocities of 0.8-1.8 m/s and water temperatures of 17-30C (Nico et al. 2005)

(4) Increased water flow and temperatures trigger an upstream spawning migration in spring and early summer (Nico et al. 2005)

27



28

iv) SC – Female Silver Carp reach sexual maturity at three to four years of age with a body weight of 7-14kg, while males can reach maturity in two years with a body weight of 5-13 kg (Lin 1991)

(1) Spawning activity is associated with high spring flows, and spawning areas have high water velocity, turbid water, and a temperature in the range of 18-30C; optimal water temperature for spawning is 22-28C (Lin 1991)

(2) Eggs are semi-buoyant and require current to prevent the eggs from sinking to the bottom (Lin 1991; Froese and Pauly 2001; Kolar et al. 2007)

(3) Floodplains associated with rising water levels provide nursery habitat areas for larvae and juvenile forms (Lin 1991; Froese and Pauly 2001; Kolar et al. 2007)

(4) Egg production per females varies with location and body size, ranging from 50,000 to 5,000,000 (Singh 1989; Kamilov and Salikhov 1996; Froese and Pauly 2001)

v) BHC – Female Bighead Carp reach sexual maturity at three years of age with a body weight of 7-10kg, while males can reach sexual maturity in two years with a body weight of 5-8 kg

(Huet 1970; Kolar et al. 2007)

(1) Spawning activity is associated with high spring flows (Verigin et al. 1978), and spawning areas have high water velocity (0.6-2.3 m/s), turbid water, and water temperature in the range of 18- 30C (Kolar et al. 2007)

(2) Eggs that are semi-buoyant and require current to keep them from sinking to the bottom (Soin and Sukhanova 1972; Pflieger 1997)

(3) Floodplains associated with rising water levels provide nursery areas for larvae and juvenile forms (Huet 1970)

(4) First-time spawners average 288,000 eggs (Vinogradov et al. 1966), while there is documented egg production from 478,000-1,100,000 (Sukhanova (1966) and Jennings (1988))

(5) Fertilized eggs need flowing water that keeps them suspended in water column as eggs develop. Originally thought to need long, unimpeded stretches of river (+30 miles). This is now being revised (???? Miles is enough given proper flow rates)

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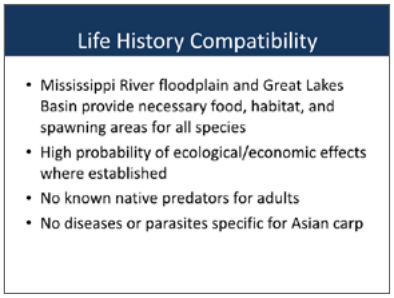
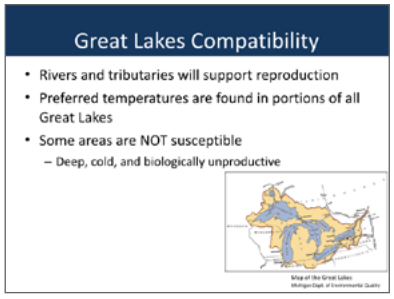
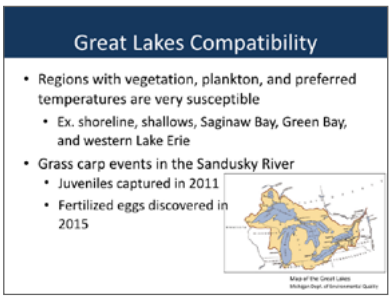
 29	a) The floodplain of the Mississippi River system and the Great Lakes Basin provides varied biophysical conditions for successful spawning, egg incubation, nursery and overwintering areas, and plentiful macrophytes, planktonic, detrital or molluscan food resources for all four species of Asian carp (Cudmore and Mandrak 2004; Kolar et al. 2007; Nico et al. 2005) b) Generally, the life history traits of Asian carps (e.g., reproductive capability, population densities, feeding habits, broad climate tolerance, mobility, and longevity) indicate that these four species have a high probability of causing ecological and economic effects where populations become established (Mandrak and Cudmore 2004; Kolar et al. 2007; Nico et al. 2005) c) No known predators at adult stage d) There are no known diseases or parasites that are likely to effectively control Asian carps that are completely specific to Asian carps (Kolar et al. 2007). It is also unlikely that any predator could be found that would prey only on Asian carps. Stocking native predators (or otherwise enhancing their abundance) might reduce the recruitment of Asian carps, however little information is available on the susceptibility of Asian carps to native piscivores. The enhancement of native predators could result in unintended effects to native prey fishes that are already stressed and is not recommended until the potential effects of such actions are better understood.
 30	1) Survivability in the Great Lakes? a) Appear to have rivers/tributaries long enough to support reproduction b) Thermally tolerant of at least a portion of all Great Lakes a) Will not likely thrive in large portions of Great Lakes Basin (deep, cold, and biological unproductive portions)
 31	2) Those regions with vegetation (GC) and healthy plankton communities (SC and BHC) are susceptible (e.g., shoreline, shallow regions, Saginaw Bay, Green Bay, Western Basin of Lake Erie, etc.) 3) Sandusky River: First direct confirmation of Grass Carp spawning in a Great Lakes tributary. a) Survivability of the 2015 spawn is still under question (until further research)

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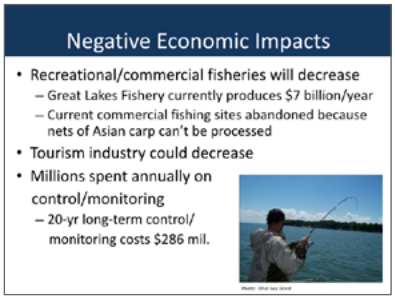

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(1) In general recreational and commercial fisheries can be impacted from change in species composition of ecosystems and abundance of particular species

(a) Traditional commercial fishing sites being abandoned because unable to process nets because overloaded with Asian carp (SC and BHC)

(2) It is possible, however, for Asian carp to provide some utility as new commercial and recreational fishery in some locations

(a) However, Asian carp commercial value is low and seems less valuable than native fish

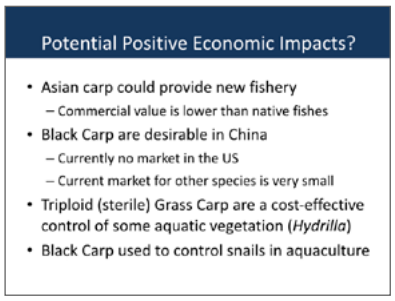
(3) Great Lakes Fishery generates economic activity of Approx. 7 billion annually

(a) Note, however some fish associated with this fishery may not be impacted by Asian carp

(4) Millions of dollars will be spent each year on integrated, long-term control and monitoring efforts

(a) estimated cost for implementation over a 20 year period is approximately $286 million. The amount of resources (e.g., staff, equipment, expertise, and funds) made available for plan implementation and how they are effectively integrated and efficiently used will largely determine the success of management and control efforts for Asian carps.

(5) Industries that benefit from sport fishing, such as tourism, will be impacted (Kolar et al. 2007)



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(1) Three species have commercial applications and are in trade in the United States:

(a) BHC has been cultured and sold as a live food fish product since the early 1980s (Kolar et al. 2007)

(b) GC have been stocked nationally by public and private entities since the mid 1970s as a biological control for nuisance aquatic weeds, (Grass Carp are also cultured and sold as a live food fish product) (Kolar et al. 2007)

(c) BC has been used since the early 1990s as a biological control for snail-borne parasites in commercial aquaculture production ponds. (Kolar et al. 2007)

(2) More specific uses, potential economic benefits, and losses associated with each species:

(a) GC –it is clear that if there was some cost-effective and selective method of removing Grass Carp from a lake system before complete eradication of submersed aquatic vegetation was accomplished then triploid Grass Carp would be an excellent control method for hydrilla (Hoyer et al. 2005)

(b) BC – Black Carp are considered one of the most desirable food fish in China and fish farmers in the United States anticipated that sales of the fish would be high in ethnic markets (see Strategy 3.1.14 and Appendix 6.3)

(i) However, to date there is neither demand for Black Carp in fish markets in the United States nor any commercial production of this fish for the live food market (see Strategy 3.1.14 and Appendix 6.3)

(ii) Currently Black Carp are used on aquaculture facilities as biological control agents for snails, which serve as intermediate hosts for several fish parasites that can kill juvenile fish and render fish flesh unmarketable (see Strategy 3.1.14 and Appendix 6.3)

(c) SC – Not cultured, largely because of their jumping habits and poor handling qualities during production, harvest, and transport (Kolar et al. 2007)

(i) That said, there are on-going efforts by commercial enterprises to develop products and establish markets for wild-harvested Silver Carp

(d) BHC –The current market for live Bighead Carp in the United States is limited and easily saturated (Stone et al. 2000)

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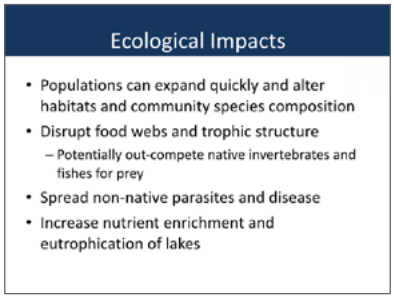

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Ecological Impacts

(i) In general can expand rapidly and change the species composition of ecosystems

ii) GC – have the potential to:

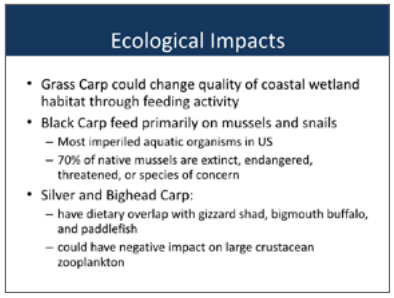
(1) Alter habitats significantly and affect native communities adversely through interspecific competition with invertebrates and other fishes (Nico et al. 2006)

(2) Decrease refugia for aquatic organisms (Nico et al. 2006)

(3) Modify preferred fish habitats; increase nutrient enrichment and eutrophication of lakes (Nico et al. 2006)

(4) Disrupt food webs and trophic structure (Nico et al. 2006)

(5) Spread nonnative parasites and diseases (Nico et al. 2006)



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Ecological impacts

iii) Black Carp feed primarily on mussels and snails, collectively the most imperiled aquatic organisms in the United States; nearly 70 percent of North American mussels are listed as extinct, endangered, threatened, or of special concern (Johnson and Butler 1999; USFWS 2005)

iv) Silver Carp are believed to affect many native species adversely because they feed on plankton, the primary food source for mussels, larval fish, and several adult fishes. (Laird and Page 1996; Fuller et al.1999)

(1) Dietary overlap between Silver Carp with gizzard shad and bigmouth buffalo in the Illinois and Mississippi rivers (Sampson 2005)

(2) Silver Carp have the potential to influence large crustacean zooplankton negatively and to alter food web interactions, thereby potentially affecting other native aquatic organisms (Kohler et al. 2005; Sampson 2005)

(3) Field studies to investigate a decline in planktivorous species in areas with abundant Silver Carp populations are lacking

(4) Pose a threat to human safety due to their jumping behavior when startled; have caused numerous personal injuries and property damage to recreational boaters and fishers (Kolar et al. 2007)

v) BHC – Although direct species interactions are not understood fully and competition is difficult to document in large and dynamic river systems (Kolar et al. 2007), the potential of increasing populations of Bighead Carp to affect native species at all life stages is a concern

(1) Bighead Carp are believed to affect many native species adversely because they feed on plankton, the primary food source for mussels, larval fish, and several adult fishes (Laird and Page 1996;Fuller et al. 1999).

(a) There is dietary overlap between Bighead Carp with gizzard shad (Dorosoma cepedianum) and bigmouth buffalo (Ictiobus cyprinellus) in the Illinois and Mississippi rivers. (Sampson 2005)

(b) There is also demonstrated dietary overlap between age-0 Bighead Carp and age-0 paddlefish in mesocosms (Schrank et al. 2003)

(c) Bighead Carp have the potential to influence large crustacean zooplankton negatively and to alter food web interactions, thereby potentially affecting other native aquatic organisms. (Kohler et al. 2005; Sampson 2005)

(d) Field studies to investigate a decline in planktivorous species in areas with abundant Bighead Carp populations are lacking.

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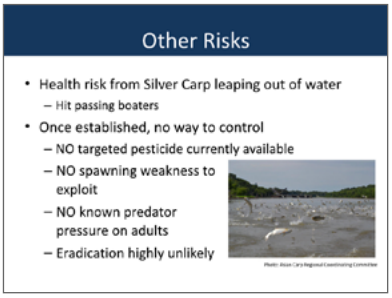
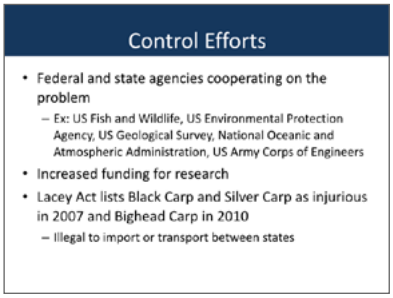
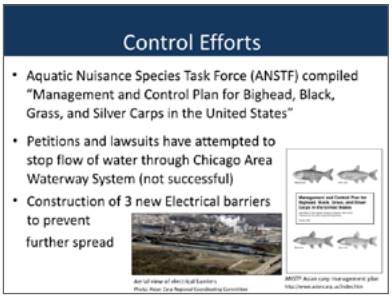
 36	a) Other: i) Health risk associated with SC leaping from water. Approximately 1 million boats and personal watercraft operate in Great Lakes Basin ii) Once established likely no way to control; prevention is key --- eradication is likely not possible (1) No targeted pesticide known (2) No apparent weakness in spawning behavior to exploit (3) No predator pressure to control
 37	What is being done a) Federal response and state regulations: i) Federal: (1) Use of Aquatic Nuisance Species Task Force (ANS Task Force); ANS Task Force is chaired by Fish and Wildlife Service and NOAA but supported by USEPA, USGS, and USACE (a) Established under the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (Act, 16 U.S.C. 4701-4741) (b) ANS Task Force has complied "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States" --- 7 board goals divided into 133 short- and long-term recommendations; see specific goals below in section "2.b.i" (2) Commission on Environmental Quality announced Asian Carp Control Framework in 2010 to outline actions and fund existing control activities (3) Construction of three electrical barriers (4) Development of Asian Carp Regional Coordinating Committee (EPA Great Lakes Program leads) (5) Congress, under Water Resources Development Act, directed the USACE to conduct multiple study to prevent spread (Interim Studies I-III) (6) Lacey Act lists BC and SC as injurious in 2007 and BHC as injurious 2010
 38	What is being done (7) Petitions and law suits have attempted to stop flow of water through CAWS none have been successful (8) Funding for Asian carp response actions and research has increased (9) There is continued push for Congress to grant new authorities to agencies to undertake prevention measures ii) State: (1) See state transport rules located in "Summary of state Grass Carp importation regulations" in "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States" prepared by the Asian Carp Working Group (a) Table 6.1.1 ---- "Summary of state regulations pertaining to import, possession, or stocking of Bighead, Black, Grass, and Silver Carps in private waters (as of 8/2007). Regulations are categorized as either prohibited, restricted (i.e., permit required), or not restricted (i.e., permit not)" (b) Table 2.3.1 ---- "Summary of state Grass Carp importation regulations (current January 2006). Information provided by the USFWS Triploid Grass Carp Inspection and Certification Program."

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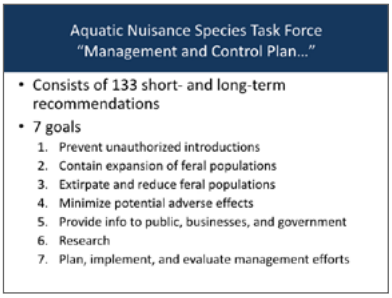

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a) Management and control goals

i) "Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States". Submitted to the Aquatic Nuisance Species Task Force in Oct 2007 and prepared by the Asian Carp Working Group

Conover, G., R. Simmonds, and M. Whalen, editors. 2007. Management and control plan for

Bighead, Black, Grass, and Silver Carps in the United States. Asian Carp Working Group,

Aquatic Nuisance Species Task Force, Washington, D.C. 223 pp.

(1) Goal 1: Prevent accidental and deliberate unauthorized introductions of Bighead, Black, Grass, and Silver Carps in the United States.

(2) Goal 2: Contain and control the expansion of feral populations of Bighead, Black, Grass, and Silver Carps in the United States.

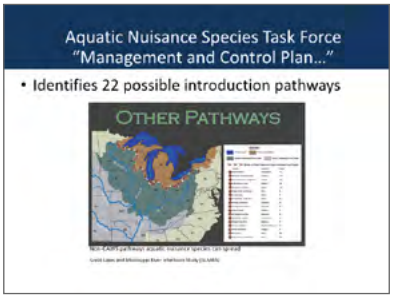
(3) Goal 3: Extirpate, or reduce to levels of insignificant effect, feral populations of Bighead, Black, Grass, and Silver Carps in the United States.

(4) Goal 4: Minimize potential adverse effects of feral Bighead, Black, Grass, and Silver Carps in the United States.

(5) Goal 5: Provide information to the public, commercial entities, and government agencies to improve effective management and control of Bighead, Black, Grass, and Silver Carps in the United States.

(1) Goal 6: Conduct research to provide accurate and scientifically valid information necessary for the effective management and control of Bighead, Black, Grass, and Silver Carps in the United States.

(2) Goal 7: Effectively plan, implement, and evaluate management and control efforts for Bighead, Black, Grass, and Silver Carps in the United States.



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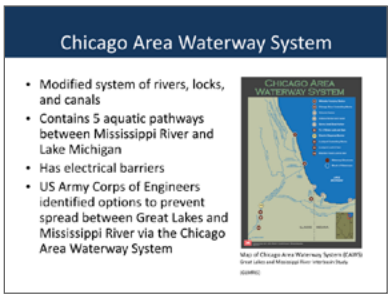
Management and control goals

i) Possible introduction pathways

ii) Twenty two are highlighted in ANS Task Force report.



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CAWS (Chicago Area Waterway System)

i) Contains modified rivers, locks, and canals to control water movement through Chicago metropolitan area.

(1) Connected in 1848 through 97-mile canal called Illinois and Michigan Canal.

(2) Now modified to include Chicago Sanitary and Ship Canal, North Shore Channel, and Cal-Sag Channel

(3) 70% of total annual flow out of CAWS is wastewater discharge

ii) Electric barriers currently employed

iii) CAWS is focus of recently released GLMRIS report that outlines 8 options identified by the USACE to prevent the spread of Aquatic Nuisance Species between the Great Lakes and the Mississippi River Basin

(1) Five aquatic pathways between Mississippi River and Lake Michigan

(a) Wilmette Pumping Station (IL)

(b) Chicago River Controlling Works (IL)

(c) Calumet Harbor (IL)

(d) Indiana Harbor (IN)

(e) Burn Small Boat Harbor (IN)

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GLIMRIS report:

i) Report outlines potential plans for decision makers (eight of them); a recommended plan was not selected by the Corps. Their task was not to select but to provide viable options.

ii) Many agencies and scientists feel that ecological separation (physical barriers) is likely the only solution

iii) These individuals recognize the obvious impact on recreational and commercial vessels and flooding in metropolitan areas

iv) Five strategies:

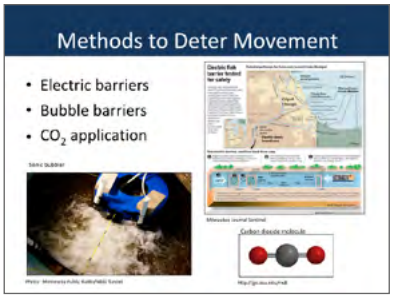
(1) Nonstructural controls (education, outreach, removal, pesticide use, etc.)

(2) Structural ANS control strategies (electric barriers, ANS treatment plants, Locks, physical barriers)

(3) Buffer zones (ANS treated area between control strategies)

(4) Hydrologic separation (use of physical barriers)

(5) Hybrids (combination of above four)



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Approaches to deter movement:

(1) Electric barriers

(2) Bubble barriers

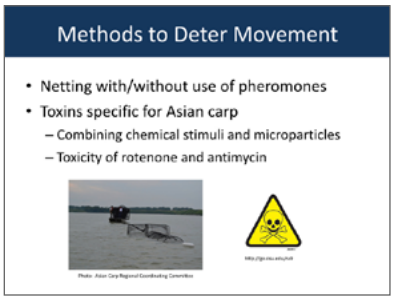
(3) Carbon dioxide application

(4) Fish poison that target Asian carp

(a) Integrating chemical stimuli and microparticles

(b) Toxicity of rotenone and antimycin

(5) Various netting approaches (some used in concert with pheromones)



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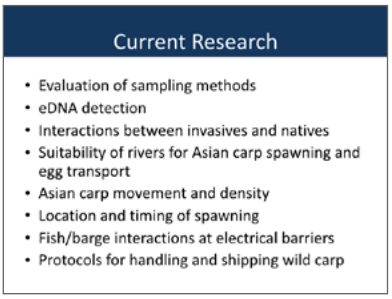

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Current and ongoing research:

(1) Evaluation of sampling gear to capture
(2) Assessment of recruitment/reproduction
(3) Spawning movements
(4) Harvest simulation models
(5) Use of hydroacoustics to determine density and movements
(6) Investigations into recruitment sources
(7) eDNA assessment:
    (a) Can it be used as early detection tool (strengths and short comings; A positive eDNA result tells researchers if Asian carp genetic material is present in an area, then that area may be a good place to use other sampling tools, such as netting, to look for signs of live Asian carp. However, it doesn't tell researchers is if the genetic material came from a live or dead fish, one fish or several, or if the eDNA may have been transported from other sources (e.g., navigation vessels or fish-eating birds))
    (b) Biotic and abiotic effects on eDNA degradation
(8) Competitive interactions between invasives and natives
(9) Developmental rate and behavior of early life stages of Bighead and Silver Carp
(10) Egg transport; assessing which rivers are most suitable
    (a) Hydrology assessment (e.g., length, flow rates)
    (b) Water quality
    (c) Water temperature
    (d) Water attribute (e.g., dissolved oxygen, water hardness)
(11) Demographic responses to Asian carp harvest
(12) Niche modeling to determine the possible movements and spread of Asian carp
    (a) Bioenergetics modeling (determine habitat suitability; e.g., ample food, appropriate water temperature, oxygen availability, etc.)
    (b) Thermal and hydrological suitability for Lake Erie and its tributaries
(13) Assessment of current genetic diversity of Asian carp
(14) Location and the timing of Asian carp spawning
(15) Movement by use of radio tagged Asian carp
    (a) Distribution and movement of small Asian carp in the Illinois waterway
(16) Diet analysis to evaluate degree of foraging overlap between Asian carp and native fishes
(17) Assess fish and barge interactions at the electric barrier
(18) Determine shipping, handling, and data protocols for wild captured Black Carp and Grass Carp

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a) Needed research – information gaps
    i) Actual economic impact that could be felt across different regions of country (note, should not wait to control movement while assessment being conducted)
    ii) Again, information to be added from Wisconsin's work (Titus' research)
b) Other:
    i) Need concerted effort to apply science and work toward control techniques
    ii) Need government commitment (US and Canada); e.g.:
        (1) Funding
        (2) Legislation
        (3) Establishment of accountability


Sea Grant
Great Lakes Network


THE OHIO STATE
UNIVERSITY


Great Lakes
RESTORATION


ASIAN CARP