Limiting Dispersal of Asian Carp at Lock and Dam Facilities in the Ohio River Basin

Participating Agencies: Kentucky Department of Fish and Wildlife Resources (lead), West Virginia Department of Natural Resources, United States Fish and Wildlife Service Carterville FWCO, and United States Army Corps of Engineers

Introduction: The national Aquatic Nuisance Species Task Force Asian carp management plan outlines the importance of limiting continued dispersal of Asian carp throughout the river basins they inhabit. Asian carp navigate many of the dams in our large rivers (Upper Mississippi, Illinois, and Ohio Rivers; Garvey et al. 2014; Tripp et al. 2014). However, in select locations, this movement may be limited to passage through lock chambers. This project specifically addresses limiting Asian carp movement by focusing efforts on lock and dam facilities that create pinch points, or areas where upstream movement is already limited. At these pinch points, movement may be further limited by creation and implementation of barrier technologies such as sound, CO_2, electricity, or water guns, or by alteration of operational methods at existing facilities (e.g. altering lock operation and flow regimes; Best Management Practices, BMP's).

Electric barriers, sound barriers, water gun technology, and CO_2 barriers are in testing or use in the fight against Asian carp. A suite of barrier technologies (integrated pest management) may be the best approach to stop movement of Asian carp. Each technology and specific site will require rigorous testing and coordination between multiple agencies prior to implementation.

While novel technologies provide opportunities to limit upstream movement of Asian carp, evaluation of current lock and dam operational methods may also provide opportunities. In some lock and dam locations, United States Army Corps of Engineers (USACE) officials are considering operational changes that limit movement of Asian carp and other aquatic nuisance species through lock chambers. For example, a lockmaster may keep a lock chamber closed until the gates open for boat passage, preventing passage of Asian carp the majority of the time. Furthermore, there was a large Asian carp die off in the Lake Barkley tailwaters on the Cumberland River in the spring of 2014. USACE officials and KDFWR are currently exploring ways to recreate the conditions that contributed to that die off. BMP's such as this could be effective at all lock and dam operations, but especially in locations where passage of Asian carp is already limited such as McAlpine, Meldahl or Cannelton on the Ohio River and multiple dams on the Tennessee and Cumberland Rivers.

Objectives: The objectives of this project are broken down into two sections including "barrier technology" and "operational guidelines" at lock and dam facilities.

Barrier Technology

1) Establish an ORFMT USACE liaison who would handle these projects and other coordination between agencies.
2) Create a list of existing barrier technologies and associated contacts and their current status in other basins.
3) Create a list of potential lock and dam sites and associated contacts where field testing may be implemented.
4) Develop site specific study designs to test applicability/feasibility of proposed barrier types.
5) Create assessment project plans that assess effectiveness and cost of barrier programs.

Operational Guidelines

1) Identify lock and Dam operation BMP's that minimize Asian carp passage, or that create conditions that favor Asian carp removal.
2) Work with USACE partners to identify key contacts and locations to target lock and dam operation BMP's and determine feasibility of implementation.
3) Develop site specific study designs to test applicability/feasibility of proposed guidelines.
4) Implement BMP's where feasible.

Methods: Because many lock and dam facilities provide a pinch point to Asian carp movement, the current lock and dam infrastructure in the Ohio River Basin may provide an opportunities for limiting dispersal of Asian carp. Efforts will fall into one of two categories: "barrier technologies" and "operational guidelines." Each case requires coordination between the Ohio River Fish Management Team (ORFMT) and the managing entity (USACE) or research institution (USGS). To coordinate among various managing entities, the ORFMT will designate a liaison to establish efficient lines of communication.

Barrier Technology

There are currently many technologies available as potential barriers to the dispersal of Asian carp. The lock and dam liaison will compile a list of current technologies, their current status in terms of development and potential deployment, hurdles to their deployment, and lead investigators of projects involving each technology. Each technology will be ranked based on its status, cost, and expected effectiveness. The ORFMT will engage USACE officials to discuss the potential implementation of barrier technology at lock and dam facilities. When potential sites are chosen, the liaison and barrier technology partners will work together to create specific project plans to implement barrier technologies and assess the effectiveness of each project.

Operational Guidelines

The USACE is responsible for operation and maintenance of lock and dam structures in the Ohio River Basin, which includes multiple USACE districts. The lock and dam liaison will determine

the appropriate level of contact in each district and schedule formal discussions regarding the potential to limit Asian carp passage via changes in lock and dam operations . The liaison will work with the USACE to develop a project plan to implement new operational guidelines (BMP's) and sampling plans that will assess their effectiveness.

Results/Discussion:

At the outset of this project in 2015, the objectives included the creation of a standalone position to serve as liaison to the USACE in moving barrier projects forward. Because multiple Ohio River Basin Asian carp projects are closely intertwined, the ANS coordinator position within KDFWR is in the best position to assume the lead role in gathering information and creating contacts for lock and dam barrier projects at the time.

With the help of USFWS and USGS coordinators, interest in lock and dam projects in the Ohio River Basin grew consistently through 2015 through the creation of critical contacts among partner agencies. Understanding that the USACE controls lock and dam facilities in the basin, a growing partnership with the USACE will ensure successful consideration of future barrier projects. In 2015 the USACE initiated the planning and information gathering process that may lead to barrier implementation in the Ohio River basin. One path towards barrier implementation is via the USACE 408 process whereby non-federal partners request the USACE consider a project for implementation. Due to the need for gathering additional information in a substantial planning process, specific projects will not be proposed through this process prior to FY2017 for the Ohio River Basin. The USACE also developed a Scope of Need (SON) that functions as a proposal to the USACE research branch, U.S. Army Engineer Research and Development Center (ERDC) to consider collecting data that is necessary for identifying barrier placement locations. The USACE has taken the lead on developing the aforementioned proposals with the support and coordination of the Mississippi Interstate Cooperative Resource Association and the ORFMT.

Site Selection

There are many considerations in choosing an appropriate site for a potential barrier. Depending on the type of barrier being considered, factors such as physical site characteristics, real estate requirements, construction access, utility availability, presence of adjacent diversion area for fish, and proximity to the invasion front should be considered (USACE 2010). Proposed sites should be ranked according to probability of success, engineering feasibility, environmental and social acceptability, cost efficiency, timely deployment, navigation impacts, and public safety impacts.

Barrier Technologies

Efforts to define potential barrier technologies have been considered in the context of limiting Asian carp passage since 2004 in the Upper Mississippi River and Great Lakes Basins(Wilken 2004, USACE 2010, USACE 2012, GLMRIS 2012). Noatch and Suski (2012) also provided a

thorough overview of barrier technologies to limit fish passage. The following information is a brief summary of information gathered from publications and personal communication with researchers working on Asian carp barrier technologies that will be considered for the Ohio River Basin. Table 1 provides a brief overview of each potential barrier type described below.

Electric Barriers

Electricity has been used in fisheries sampling since the 1950's. When electrical energy is applied to water, it is transferred to fish and leads to taxis, immobilization, and trauma. As a result, electric barriers can be effective barriers to fish movement. Electric barriers have been used to varying degrees of success deterring migrating lampreys, limiting entrainment of fish at power cooling intakes (Schilt 2007), and limiting passage of fish in irrigation canals (Clarkson 2004). The most famous electric barrier is located in the CSSC to prevent Asian carp movement into Lake Michigan. The effectiveness and utility of that barrier project has been studied since 2010, the last time an Asian carp was collected above the barrier. Most accounts suggest that the barrier has been effective at keeping adult Asian carp from entering Lake Michigan, but the success of the CSSC electric barrier should be considered within the context of the broader integrated pest management approach that is being applied in the Illinois River to keep Asian carp from testing the effectiveness of the barrier.

In general, electrical barriers are very expensive to implement, especially at a large scale such as in the CSSC. They must be located near a sufficient power source, and are prone to deactivation during power outages, human error, and maintenance issues (Clarkson 2004). Despite their success with adult fish, they can be size and species selective. In waters where barge transport is common, such as the large rivers of the interior United States, fish and their larvae can cross the barrier in dead spaces trapped between barges (Sam Finney, personal communication). Electric barriers may have a place in an integrated pest management approach such as the proposed Brandon Road Lock and Dam on the Illinois River, but their application may be limited on larger systems such as the Mississippi and Ohio Rivers.

Strobe Lights

Arrays of flashing lights have the potential to deter some fish from an area, and may attract others. Strobe lights have been 65-95% effective at deterring American eels, *Aguilla rostrata*, and have been used to repel American shad, *Alosa sapidissima*, juveniles(Wilken 2004). This barrier type is not useful as a standalone barrier due to variable results in previous studies, species-specific results, and a reliance on clear water for success. The application of strobe lights in the turbid waters of large rivers where Asian carp are currently common is limited.

Bubble Curtains

A fence or "curtain" of bubbles in the water column creates a potential visual deterrence to the passage of fish. Bubble curtains by themselves create no light, and thus have a limited

application in turbid rivers (Solomon 1992). Their combination with sound and or strobe lights has shown promise in deterring fish (Wilken 2004). The Management and Control Plan for Bighead, Black, Grass, and Silver Carp in the United States as well as the Asian Carp Control Strategy Framework identify the potential application of this technology including recommendations for use during shutdowns of the electric barrier in the CSSC. Testing of a hybrid system in a tributary of the Illinois River limited passage of Asian carp. In that study, few Asian carp tagged below the barrier were later captured above the barrier (2 of 575), but it is not clear how many fish challenged the barrier (Ruebush et al. 2012). As a result, rigorous field-testing is needed to confirm results.

Acoustic Barriers

Sound deterrence systems have been used most commonly to deter fish from passing through power generating stations (Gibson and Myers 2002), but interest in the use of acoustic barriers to limit Asian carp movement has grown in recent years. Asian carp are a part of the ostariophysan fishes, which have a connection between the gas bladder and inner ear. As a result, they are considered "hearing specialists", with a sensitivity to sound unlike other fishes (Schilt 2007). This sensitivity to sound creates the potential to limit movement of Asian carp using complex sound with little impact to other fishes. Laboratory studies of Asian carp in raceways and ponds show a pronounced phonotaxic response of Asian carp to sound (Pegg and Chick 2004, Taylor et al. 2005, Vetter et al. 2015, USGS personal communication). Effectiveness in the field is dependent on understanding the impacts of bottom morphology, hydrology, and angle of sound. Because acoustic deterrence systems have a relatively low cost and show promise in lab settings, studies are underway in 2016 to address information needs including field-testing. Additional studies are underway at Lock and Dam 8 on the Mississippi River to limit the passage of Asian carp through Lock chambers using underwater speakers. Proposed work at Lock and Dam 19 on the Mississippi River has met roadblocks as researchers work to create a useful study.

Velocity Barriers

Barriers that create areas of increased water velocity have been used to prevent the passage of lampreys (Katopodis et al. 1994). A successful barrier must feature velocities above the aerobic swimming capacity of the species in question over a length greater than the distance covered in an anaerobic burst. As result, their application is species specific, and the swimming ability of the species in question must be known. The application is also limited to smaller scales where water velocities can be controlled.

Hypoxia and Hypercapnia

Chemical toxicants such as Chlorine have been used to prevent biological fouling of water intakes for many years. Variation in oxygen or carbon dioxide levels can affect water chemistry and deter fish passage as well. This method requires testing of water chemistry tolerances for target and non-target fishes. The result is a barrier that is not size-selective and no long term

toxicity remains in the water. To date there has been a lack of field and ecosystem scale testing on these methods. Schreier et al. (2008) suggested creating a hypoxic zone in the CSSC to limit movement of round goby between Lake Michigan and the Mississippi River Basin. The result was a study determining the feasibility of a gas bubble curtain delivering purified nitrogen or carbon dioxide to the water column. Increased flows can cause failure of these systems in large rivers. Barriers of this type come with complex engineering challenges that can be very expensive to overcome. There are plans in 2016 to test how different injection systems distribute these gases in field settings.

Pheromones

Secreted chemical odors are used by fish to elicit behavioral responses in reproduction, to attract the opposite sex, and predator avoidance, to warn neighbors of impending danger. Chemicals could be collected or created and placed in the water to either attract fish to an area where they may be captured, or conversely exclude them from an area. Attraction pheromones have been used extensively in the management of invasive sea lampreys, while alarm pheromones have been identified for common carp (Sorensen and Stacey 2004), showing the potential for use as a deterrent. Despite these examples, the use of pheromones as attractants and deterrents is in its infancy, and requires investigation into their effectiveness, procurement, and deployment. Very little research has been directed at the use of pheromones as a fish barrier.

Other Chemicals

Piscicides, biocides, and species-specific toxins may be considered as barriers in relatively small areas necessary for fish passage. Examples of their application includes the use of chlorine to limit biofouling at water intake structures, lampricide to limit female lamprey spawning runs, and rotenone to rid an area of all fish. Drawbacks of these methods include negative effects on non-target species, negative public perception, and potential persistence in the environment. These methods are most useful as controls during maintenance to other fish barriers such as the application of rotenone in the CSSC in 2009 (Buck et al. 2014).

Conclusions

Nonphysical barriers offer flexibility in deterring the movement of Asian carp that physical barriers do not. Because they are not permanent, they pose no restriction to navigation or other potential water uses. When complete restriction is necessary, as in the case of Asian carp, nonphysical barriers may not succeed indefinitely.

When considering the use of nonphysical barriers, a suite of information is necessary in deciding the appropriate barrier to use, and the subsequent location for its use. All efforts to use barriers in limiting Asian carp dispersal should include initial understanding of each specific river system's physical properties (hydrology and bathymetry), chemical properties (water quality), and necessary uses. A complete understanding of the distribution and abundance of Asian carp

in each system is also critical. As more information is available on the potential uses of specific nonphysical barriers, a suite of criteria should be created to evaluate the usefulness of proposed barriers throughout the Mississippi River Basin.

Operational guidelines:

USACE lockmasters at each lock and dam facility have control over how locks and dams are operated. As a result, investigation into lock and dam operations should begin at the local level. Asian carp researchers in the Ohio River Basin established contact with officials at each lock and dam facility during the telemetry project. In each case, USACE officials were interested in our projects, and willing to assist. The next step will be to sit down with each lockmaster and discuss ideas of how we can adjust operations to limit Asian carp movement. At the same time, little is known about how Asian carp move through locks and dams in the Ohio River. Ongoing telemetry work will continue to inform this discussion.

Recommendations: Implementation of effective barriers to Asian carp movement within the Ohio River Basin is a priority in limiting the negative impacts of Asian carp on native ecosystems. Unfortunately, a paucity of information exists on many barrier technologies, and field investigations can be slow and expensive. As investigation of the utility of barrier technologies continues, projects that provide understanding of the physical properties of the Ohio River and the biology of Asian carp and native fish in the Ohio River should continue. With the leadership of the USACE, Ohio River Basin partners will pursue the shortest path to a project that implements an effective barrier to Asian carp movement in the Ohio River.

Project Highlights:

- Creation of important partnerships in 2015 have led to effective communication and information sharing between agencies.
- USACE presented information on a project sponsorship program that can result in implementation of projects at USACE facilities in a relatively short time.
- USACE submitted a SON to ERDC to create a checklist for collecting information necessary to review potential lock and dam facilities for use with sound barriers.
- Compilation of potential barrier types and their status as fish deterrents.

Table 1. Summary of non-physical barriers for consideration in deterrence of bigheaded carps. Also listed are deployment conditions where barriers are likely to be successful, advantages and disadvantages of different barrier types, and representative citations. Altered from Noatch and Suski (2012), MNDNR (2004), and GLMRIS (2012).

Barrier/Deterrent	Deployment conditions	Advantages	Disadvantages	Comments
Electricity	Site with adequate power source; appropriate water conductivity	Flexible deployment, very effective against recruited fish	May not affect smaller fish	Public Safety concern
Strobe lights	Consistent low water turbidity	Less infrastructure, potentially lower cost	Lower effectiveness, especially in daytime. Variable by season, time of day.	Lock entrance deterrent
Sound (Sound Projector Array)	Site with adequate acoustic characteristics	Effective across a wide range of environmental conditions	Variable effectiveness; frequencies must be chosen per species	Highest potential at lock channel entrance
Bubble curtains	Low water turbidity, relatively shallow water, low flow	Few as a stand-alone deterrent: may enhance other deterrents	Low effectiveness, may not work under all conditions	High flow is limiting
SPA based acoustic bubble curtain	low flows	enhances effectiveness of standard BAFF	Not effective in flowing waters	Highest potential at lock channel entrance
Hybrid (sound-bubble-strobe-light)	low turbidity, minimum flow	hybrid systems can be more effective	System maintenance, variable with temperature and flow	More study is needed
Water velocity	Target species that is a weak swimmer; narrow channel with adequate water flow	Selectively excludes nuisance species	Major modification to channel; few sites meet criteria	Navigational impacts
Hypoxia and hypercapnia	Relatively shallow water, space needed for bulk gas storage	Potential to exclude virtually all fish	Large investment of research time and capital	CO^2 under investigation
Pheromones	Confined spaces and (or) short term application	Potential to selectively exclude particular fish	Time and effort to procure pheromones in bulk quantity	
Chlorine	Highly constricted deployment space	Potential to exclude virtually all fish	Harmful to almost all aquatic fauna; negative public perception	

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