

**MICHIGAN DEPARTMENT OF NATURAL RESOURCES
AND ENVIRONMENT**

**PROPOSED PLAN FOR THE PREVENTION, DETECTION, ASSESSMENT, AND
MANAGEMENT OF ASIAN CARPS IN MICHIGAN WATERS**



(Bighead carp)



(Black carp)



(Grass carp)



(Silver carp)

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1) EXECUTIVE SUMMARY

This document was prepared in response to a charge from the Michigan Department of Natural Resources and Environment (hereafter “DNRE” or “Department”) Fisheries Division Management Team to:

Develop a draft plan for Michigan to address potential monitoring and assessment needs for Asian carps.

Questions the Fisheries Division Asian Carps Working Group (D. Clapp, J. Mistak, K. Smith, M. Tonello) ultimately attempted to address in this document include the following:

- What does the Department need to do to adequately address the threat of Asian carp species invading Michigan waters?
- What sampling strategies are appropriate in addressing this threat?
- What should our response be if Asian carps, either isolated individuals or abundant populations, are detected in Michigan waters?
- What are the pros and cons of various possible management strategies?
- What types of resources (both financial and human) are necessary to adequately address this threat?

This is not intended as a rapid response plan, but rather as the beginning of a comprehensive strategy for addressing the threat of Asian carps dispersing, or being introduced, into Michigan waters. In this plan, the phrase “Asian carps” refers to black carp, grass carp, bighead carp, silver carp, and large-scale silver carp (an alphabetical list of common fish names and their corresponding scientific names is provided in Appendix B). Since 2007, it has been illegal to transport or possess live Asian carps (any species) in Michigan.

In developing this document, our group chose to follow the outline suggested in “*A Model Comprehensive State Management Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species*” (Glassner-Shwayder 1996). This model plan is based on the findings of a regional workshop titled “*Aquatic Nuisance Species/Coastal Management Programs: Toward a Regional Strategy in the Great Lakes Basin*”, funding for which was provided by the National Oceanic and Atmospheric Administration (NOAA) to the Michigan Department of Natural Resources (MDNR). The model plan was presented to the Great Lakes states as guidance in developing comprehensive state management plans under Section 1204 of the federal *Nonindigenous Aquatic Nuisance Prevention and Control Act* (P.L. 101-646) (NANPCA).

Our plan contains eight sections (Executive Summary, Asian Carp Background, Policy Background, Management Actions, Implementation, Program Evaluation, Tables, Appendices), closely following the format suggested by Glassner-Shwayder (1996). In preparing the “Asian Carp Background” and “Management Actions” sections, we relied heavily on a core group of previously-published reports and plans, including: Conover et al. (2007), Kolar et al. (2007), Mandrak and Cudmore (2004), and Minnesota DNR (2007) [Note: Original citations from these core reports were generally not carried forward into our report – see *American Fisheries Society Style Guide*; Section 8.6, “References not seen”. Additional fact checking and citation of original references may be included in revised versions of our report.]. From these and other reports and literature, our group first identified 145 strategies that we felt were important in addressing the charge given us by the Management Team. These were subsequently reduced,

through in-depth discussion, to a list of 22 strategies that we believe should be integral parts of a DNRE Asian carps management plan.

Within this report, common strategies are combined under five goals: prevention, communication, detection, assessment, and management. These goals are presented in what our group feels to be the priority order for management action. Prevention and communication are of immediate importance. If Asian carps are detected in Michigan waters, then we will be forced to undertake assessment and management actions. We restricted ourselves almost entirely to analysis and documentation of strategies and actions that could be directly implemented by DNRE and other Michigan agency staff. So, while our group feels that implementing ecological separation (for example, between Lake Michigan and the Mississippi River system) is probably the strategy with the highest likelihood of success, we did not directly include this as a strategy within our plan since the DNRE cannot independently implement separation. Likewise, while political action has some likelihood of success in preventing Asian carps from reaching Michigan, such action is not directly within our scope of authority.

As suggested by Glassner-Shwayder (1996), and as included in other plans we reviewed, a synopsis of our plan is included as an implementation table (Table 4). This table includes recommended lead agencies or groups, likely collaborators, general cost estimates, current implementation status, and suggested implementation actions for each of our goals / strategies. This table is a good starting point at which to get a feel for the scope of this plan. More detailed discussion of each strategy, recommended specific actions, and example scenarios are included within Section 4 (“Management Actions”).

While further discussion and evaluation of the details of this plan will be critical, immediate recommendations can be summarized as follows:

- Prevention is the highest priority goal, but also the goal that we have perhaps the least ability to realize through Department actions. It is well-documented that, once introduced, aquatic invasive species (AIS) are difficult to eradicate and expensive to manage.
- Communication will be critical to preventing the dispersal of Asian carps into and throughout Michigan waters. Kolar et al. (2007) describe a public education campaign to be the only tool available for immediate use in controlling the spread of Asian carps. The plan outlines six specific strategies for communication with the public and agency partners. A priority will be timely development of an effective public reporting system (see below; surveillance).
- We are relying heavily on the promise of environmental DNA (eDNA) technology, as well as on efforts of public and agency partners, as means of early detection of Asian carps in Michigan waters. Our group feels that, due to the high cost of conventional fisheries assessment techniques and the low likelihood of success of these techniques for early detection of Asian carps, these techniques should not be employed as a priority component of a detection program.
- While we feel that agency assessments are not an ideal means of early detection, assessments will be an important precursor to management if Asian carps are detected in Michigan waters. Our group recommends evaluation of Asian carps’ abundance and determination of their effects on Michigan aquatic habitats and resident fish species as the first steps in developing specific management strategies. In this document, we provide examples of generalized assessment plans for a variety of state waters.

- Finally, we provide a preliminary analysis of six management strategies that could be employed, with some likelihood of success, by the DNRE and partner agencies. These strategies range from relatively less costly implementation of best management practices (Hazard Analysis and Critical Control Point – HACCP) by Department field crews and private aquaculture interests to more costly strategies involving incentives to commercial fishers or chemical reclamation of large tributaries. We emphasize here that, ***while management will likely be a difficult undertaking, our six recommended strategies carry with them a reasonable expectation of success. We do not believe that attempts at management of Asian carps are futile, and “writing off” Michigan waters in which Asian carps have been detected is not a responsible approach.*** However, the costs of all of our recommended actions are high, relative to the costs of the preferred alternative – not having to manage Asian carps in Michigan’s waters.

Our group feels that the Department should begin as soon as possible to act on the recommendations outlined in this report. To facilitate such action, we have highlighted the following strategies that our group feels are most critical to immediately addressing the threat of introduction of Asian carps to Michigan waters.

- The first step that should be taken is formation of a Michigan Asian Carps Task Group, with initial membership coming from DNRE and Michigan Department of Agriculture (MDA) (see Goal II, Strategy 6). Initial charges to this task group should be to implement a public education and communication plan (Goal II), evaluate potential regulatory changes (Goal I), investigate and implement (as appropriate) new technologies (e.g.; eDNA, pheromone attractants, deterrent technologies) for containing and managing Asian carps (Goal V, Strategy 6), and seek sources of additional funding to implement priority strategies. Because it may take some time for an inter-departmental task group to be convened and operational, our Department group will work within the DNRE to begin implementing some of these strategies, until such time as a larger, state-level effort is in place. Ultimately, these efforts will likely be integrated with those of the AIS Core Program, coordinated by the Water Resource Division.
- A public education campaign is a critical tool for use in controlling the spread of Asian carps (Kolar et al. 2007); our recommended communication and education strategies are described in detail under Goal II. Immediate attention should be given to addressing Strategy 5 (communicating with the public concerning recent developments and Department strategies) and Strategies 1-3 (getting information to the public concerning identification of Asian carps, potential ecosystem effects of invasion and establishment of Asian carps, and pertinent state and federal regulations). Other Michigan DNRE divisions should begin immediately to work with Media and Communications staff in implementing these strategies.
- As described in more detail later in this report, preventing the establishment of Asian carps in Michigan’s waters is the principal method available to avoid negative ecological, recreational, and economic effects. Preventing transport and release or improper disposal of Asian carps that may be intermixed with baitfish (Goal I, Strategy 1) and controlling ongoing and permitted fish stocking efforts to prevent inadvertent introduction of Asian carps (Goal I, Strategy 2) are two strategies that our group recommends for immediate

action. Implementing these strategies will necessitate close coordination among Fisheries Division, Law Enforcement Division, and MDA – coordination that we hope will be facilitated through formation of the interagency Asian Carps Task Group.

- Finally, we feel that quick implementation of an effective surveillance plan is critical, and will provide significant benefits by allowing us to target management actions at an early stage of invasion, should Asian carps reach Michigan waters. Environmental DNA surveillance holds great promise, and we should work to implement an eDNA surveillance program in Michigan waters within the next year (Goal III, Strategy 1). Despite the likely usefulness of an eDNA program, it is probable that members of the public – including anglers, charter captains, commercial fishers, riparian landowners, and recreational boaters – will be among the first to sight Asian carps if they do invade Michigan waters. A method should be developed as soon as possible to allow the public to report sightings of Asian carps to the DNRE (Goal III, Strategy 2). In addition, information on identifying characteristics of all life stages of Asian carps should be distributed to the public (Goal II, Strategy 1), to improve their ability to assist us in monitoring Michigan waters for introductions of Asian carps.

2) ASIAN CARP BACKGROUND

There are four species of Asian carp that currently threaten Michigan waters; bighead carp, black carp, grass carp, and silver carp. All of these species are native to fresh waters in eastern Asia, and all have been introduced to North American waters. The native ranges of these four species encompass areas that are similar in climate to Michigan (Conover et al. 2007). A fifth species of Asian carp that could potentially threaten North American waters is the largescale silver carp; although that species has not been documented in North American waters (USEPA 2007). As of April 2010, of the four Asian carp species that have been documented in North American waters, only grass carp have been documented in Michigan waters.

Asian Carp Biology and Distribution

Bighead carp

The bighead carp is a large, deep-bodied fish that can grow to lengths of nearly five feet and weights exceeding 90 lbs (Conover et al. 2007). They are characterized by a very large head, with a large toothless mouth, and their eyes, clearly seen in a ventral view of the fish, are located far forward and low on the head (Kolar et al. 2007). Bighead carp are dark gray above and cream colored below, with dark, irregular blotches on the back and sides. Bighead carp feed in benthic, mid-water, and surface environments. They feed mostly on zooplankton using gill rakers that strain plankton from the water, but will also consume algae, aquatic insects, and detritus (Conover et al. 2007). Bighead carp lack a true stomach, which requires them to feed continuously, giving them a reputation as voracious feeders that sometimes consume over 20% of their body weight on a daily basis (Asian Carp Workgroup 2010). Although a range of preferred water temperatures has been documented for bighead carp, their distribution in Asia suggests that they would be capable of tolerating the cold water temperatures that are found in Michigan waters in winter (Kolar et al. 2007).

According to Kolar et al. (2007), sexual maturity in bighead carp is dependent on climate and may be reached between ages 2 and 7, with males often maturing one year earlier than females. Of particular concern is their notably high fecundity rate, with individual females capable of producing more than one million eggs (Conover et al. 2007). North American studies have estimated fecundity at less than 800,000 eggs per female, with averages around 200,000 eggs per female (Kolar et al. 2007). Bighead carp spawn in water temperatures ranging from 64° F to 86° F (Kolar et al. 2007) and preferred spawning habitats consist of turbid, rapidly flowing areas where waters are mixing, such as the confluence of rivers or in rapids (Kolar et al. 2007). Specific spawning habitat may be needed, since bighead carp eggs are semi-buoyant and may require current to keep them from sinking to the bottom. Spawning activity often takes place during periods of rising water levels in spring and early summer, although there is evidence of bighead carp spawning as late as September or October, which may indicate they are capable of spawning more than once in the same year (Kolar et al. 2007). Bighead carp are also known to hybridize with silver carp (Kolar et al. 2007). Bighead carp can likely live up to 20 years.

Bighead carp were first introduced into the United States in the early 1970s. Through escapes from aquaculture facilities and subsequent migration and natural reproduction, bighead carp have now been recorded from the waters of 23 states and from Lake Erie (Kolar et al. 2007). Major watersheds in which they are now prevalent include the Mississippi, Missouri, Ohio, and Tennessee River systems (Conover et al. 2007). Bighead carp have naturally reproducing

populations in waters of states bordering Michigan, including Illinois, Indiana, Ohio, and Wisconsin. Of particular concern are the Chicago Waterway and Calumet River systems in Illinois and Indiana that are directly connected to Lake Michigan, and may provide a pathway for bighead carp to become established in Lake Michigan. To reach the Chicago Waterway and Calumet River systems, bighead carp migrated from the Mississippi River upstream into the Illinois and Des Plaines Rivers. Although there were five documented catches of individual bighead carp in Lake Erie between 1995 and 2003, at this time there does not appear to be a naturally reproducing population in Lake Erie (Kolar et al. 2007). The introduction pathway that resulted in these specimens of bighead carp being observed in Lake Erie is unknown (Morrison et al. 2004).

Black carp

The black carp is different in appearance and diet compared to bighead and silver carp. Black carp are a large, elongated, laterally compressed fish that can grow to lengths of nearly six feet and weights nearing 150 lbs (Nico et al. 2005). They are characterized by a pointed head with a flattened anterior portion and a small toothless mouth. Black carp are covered with large cycloid scales, and are colored brown or black, grading to a bluish gray or nearly white belly (Conover et al. 2007). They superficially resemble grass carp (Nico et al. 2005), and juveniles in particular are often mistaken for grass carp. Adult black carp feed primarily on mollusks and snails, using molar-like pharyngeal teeth to crush the shells. They are also capable of feeding in waters up to 90 feet in depth (Mandrak and Cudmore 2004). A range of preferred water temperatures has been documented for black carp; their distribution in Asia suggests that they would be capable of tolerating the cold water temperatures that are found in Michigan waters in winter (Kolar et al. 2007).

Black carp reach sexual maturity between ages 6 and 11, with males typically maturing one year earlier than females (Conover et al. 2007). Of particular concern is their notably high fecundity rate, with individual females capable of producing more than three million eggs. Black carp spawn in water temperatures ranging from 62° F to 86° F (Minnesota DNR 2007). Specific spawning habitat may be needed, since black carp eggs are non-adhesive and semi-buoyant, requiring current to keep them from sinking to the bottom. The eggs and larvae are carried into floodplain lakes, smaller streams, and low-current channels that serve as nursery areas for larval and juvenile black carp (Conover et al. 2007).

Black carp were first introduced into the United States in 1973 by private aquaculture facilities in Arkansas. Black carp have now been reported from 11 different states. Currently, the distribution of black carp in North America seems to be restricted to the southern portion of the Mississippi River watershed, although one black carp was reportedly caught in southern Illinois (Nico et al. 2005).

Grass carp

The grass carp is characterized as a large, elongated, laterally compressed fish that can grow to lengths exceeding five feet and weights exceeding 80 lbs. Conover et al. (2007) describes the grass carp as having a slightly flattened head with moderately small eyes centered on the side of the head, a body covered with large cycloid scales that appear crosshatched, and a body color ranging from blackish or olive brown on the dorsal surface to brassy or silvery white on the sides and belly. Grass carp feed primarily on submerged plants with soft leaves, although they will

also consume filamentous algae and firmer plants (Cudmore and Mandrak 2004). They possess comb-like pharyngeal teeth that are used to grind vegetation. Grass carp have also been documented as feeding on organic detritus, insects, small fish, earthworms, and other invertebrates. Grass carp can consume up to 40% of their body weight per day in vegetation. As previously described for bighead and black carps, the distribution of grass carp in Asia suggests that they would be capable of tolerating the cold water temperatures that are found in Michigan waters in winter; collections throughout Michigan since the late 1980s indicate that this is indeed the case (DNRE, file data).

Grass carp reach sexual maturity at four to five years of age in North America (Cudmore and Mandrak 2004), with males typically maturing one year earlier than females. Grass carp have a notably high fecundity rate, with individual females capable of producing more than two million eggs. Grass carp spawn in water temperatures ranging from 68° F to 86° F. Similar to other Asian carps, preferred spawning habitats consist of turbid, turbulent water at the confluence of rivers or below dams. Spawning activity has been noted to take place during periods of rising water levels, usually in spring and summer. There is evidence of grass carp spawning more than once in the same year (Cudmore and Mandrak 2004). Grass carp eggs are non-adhesive, semi-buoyant and may require current to keep them from sinking to the bottom.

Grass carp were first introduced into the southern United States in 1963 as an aquaculture experiment. Stocking of triploid grass carp as a biological control against nuisance aquatic plants is currently permitted in many states throughout the United States. Through escapes from aquaculture facilities, intentional introductions, and subsequent migration and natural reproduction, grass carp have now been recorded from the waters of 45 states and three provinces of Canada (Cudmore and Mandrak 2004). Grass carp have been captured in all the Great Lakes except for Lake Superior, although it is likely that the fish captured from lakes Michigan, Huron, Erie, and Ontario were escapees and do not represent naturally reproducing populations. Nearby States, including Indiana, Illinois, and Ohio, allow the stocking of triploid (presumed sterile) grass carp. Michigan, Wisconsin, and the province of Ontario do not allow the possession or stocking of grass carp.

The risk of naturally reproducing grass carp and the potential for significant habitat loss led to Michigan regulating this species under the Administrative Procedures Act of 1969 (Administrative Rule 299.1052). The Director of the Department of Natural Resources limited the import of grass carp fish or eggs based on a permit system. Despite the Administrative Rule, grass carp were illegally stocked in many private lakes and ponds throughout the Lower Peninsula. The state did not want to risk escapement of these fish into public waters, so ponds were typically treated (at the owner's expense) to remove grass carp. When triploid grass carp technology was developed there was another push to legalize grass carp. Other States began to allow stocking of certified triploid grass carp by permit. Triploid grass carp were promoted as being cheaper and less environmentally damaging than chemical control of vegetation (Kolar et al. 2007). The "grass carp roundups" that were performed all over the Lower Peninsula in the late 1980s must have been successful, as there are currently no documented reproducing grass carp populations in Michigan.

Despite these efforts, adult grass carp continue to be captured in Michigan waters. In 2005, MDNR staff captured a 40-inch grass carp in the St. Joseph River, Berrien County. Subsequent survey efforts in 2006 captured two individual grass carp within the same river reach. All grass carp were manually removed and inspected for development of reproductive organs, but were not

tested to determine if they were diploid or triploid. The St. Joseph River is a border water that flows through the state of Indiana, where stocking of triploid grass carp is permitted. It is likely that the grass carp encountered in the St. Joseph River were a result of escapement from ponds in Indiana during flooding or from the release of captive fish into the wild. In subsequent fisheries surveys of the St. Joseph River in 2007, 2008, and 2009, adult grass carp were again caught. This indicates that individual fish are able to survive in the St. Joseph River, yet reproduction has not been confirmed. Muskegon Lake is another body of water where multiple adult grass carp have been captured. It is unknown whether any of the individual grass carp captured from Michigan waters were diploid or triploid.

Silver carp

Smaller than bighead carp, the silver carp is a large, deep-bodied fish that can exceed lengths of three feet and weights of 60 lbs (Conover et al. 2007). Silver carp are characterized by a large, broad head, with an upturned toothless lower jaw and eyes located far forward and low on the head. Silver carp are generally silver on their sides, with a slate-gray head and dorsal surface, white belly, and a well-developed keeled abdomen that extends from the throat to the vent. Juvenile silver carp closely resemble and are often mistaken for gizzard shad (Kolar et al. 2007). Silver carp are very efficient filter feeders, as they possess specialized gill rakers that are fused into sponge-like porous plates. They feed primarily on phytoplankton, but will also consume zooplankton, invertebrates, detritus, and bacteria. Silver carp lack a true stomach, requiring them to feed continuously. Silver carp are a very active, schooling species, and they are well known for their habit of leaping out of the water when disturbed. Like bighead, black, and grass carps, silver carp should be capable of tolerating the cold water temperatures that are found in Michigan waters. There is some evidence which indicates that silver carp may be even more tolerant of cold water temperatures than bighead carp (Kolar et al. 2007). Silver carp can likely live up to 20 years.

In the southern portions of their range in Asia, female silver carp reach sexual maturity at three years of age, while males become mature at age 2. In northern portions of their range, maturity is delayed by up to two years. Of particular concern is their notably high fecundity rate, with individual females capable of producing more than five million eggs in Asian studies. North American studies have estimated fecundity at less than 350,000 eggs per female (Kolar et al. 2007). Silver carp spawn during periods of rising water levels in water temperatures ranging from 64° F to 79° F or warmer (Conover et al. 2007). Although spawning activity typically takes place in spring and early summer, there is evidence that silver carp will spawn as late as September or October, similar to bighead carp. This may indicate that they are capable of spawning more than once in the same year (Kolar et al. 2007). Preferred spawning habitat seems to consist of large, turbid rivers, with floodplains or lakes providing nursery areas for juveniles. Like bighead carp eggs, silver carp eggs are semi-buoyant and may require current to keep them from sinking to the bottom. Silver carp are also known to hybridize with bighead carp (Kolar et al. 2007).

Silver carp were first introduced into the United States in the early 1970s. Through escapes from aquaculture facilities and wastewater treatment facilities and subsequent migration and natural reproduction, silver carp have now been recorded from the waters of 16 states and Puerto Rico (Kolar et al. 2007). Major watersheds in which they are now prevalent include the Mississippi, Missouri, and Ohio River systems (Conover et al. 2007). Silver carp have naturally reproducing populations in two States that border Michigan, Illinois and Indiana. Of particular concern are

the Chicago Waterway and Calumet River systems, which are directly connected to Lake Michigan and may provide a pathway for silver carp to become established in Lake Michigan. To reach the Chicago Waterway and Calumet River systems, silver carp migrated from the Mississippi River upstream into the Illinois and Des Plaines Rivers.

Need for Prevention and Control

Of the four Asian carp species that are currently present in North American waters, only the grass carp has been observed in Michigan waters. However, each of the four species is very hardy, and if they are introduced to Michigan waters in sufficient numbers to reproduce, the introductions will most likely be permanent. If this occurs, the likelihood that they will negatively influence fisheries and ecosystems in Michigan is very high.

Bighead and silver carps

Of the four Asian carp species in North America, bighead and silver carps clearly present the most severe threat to Michigan waters. The most likely route of permanent introduction would be through the Chicago Waterway and Calumet River systems into Lake Michigan. Environmental DNA surveillance has detected bighead carp upstream of the electrical barrier (USACOE 2010) four different times as of April 2010 (Lodge 2010)¹. All four detections were in the Calumet River system, with one of the detections occurring just south of the O'Brien Lock and Dam about 7.5 miles from Lake Michigan. Environmental DNA surveillance has detected silver carp upstream of the electrical barrier in the Chicago Waterway and Calumet River systems eight different times as of April 2010 (Lodge 2010). One silver carp eDNA detection was in Lake Michigan near the mouth of the Calumet River, with another detection occurring at the Wilmette Pumping Station directly adjacent to Lake Michigan. These positive detections in and very close to Lake Michigan indicate that at least a small number of silver carp have likely already entered Lake Michigan. Whether there are enough silver carp present in Lake Michigan to reproduce and establish a permanent population is unknown. From this entry point however, both bighead and silver carps could potentially gain access to the rest of the Great Lakes and their connecting waters.

Since they are planktivores (Kolar et al. 2007), bighead and silver carps would affect the food web at its very base by overlapping with aquatic organisms that are also dependent on plankton, including mussels, larval fish, and adult fish. Fish species with potential dietary overlap include alewife, gizzard shad, bigmouth buffalo, emerald shiner, spotfin shiner, brook silverside, and juvenile yellow perch and walleye. One possible negative interaction through competition for food resources might include alewife, a very important prey item for many predatory fish in Lake Michigan including Chinook salmon. This, in turn, could negatively affect Chinook salmon populations, which are prized by sport anglers.

It is unknown where exactly bighead and silver carps would thrive in Michigan waters, if they were introduced. Kolar et al. (2007) suggest that bighead and silver carps are incapable of reproducing in lakes, and that they require rivers with 60 miles or more of undammed flowing water. The rivers in Michigan that are listed in Kolar et al. (2007) include such Lake Michigan tributaries as the St. Joseph, Grand, Pere Marquette, Big Cedar, and Ford rivers. Lake Huron

¹ As of July 2010, one bighead carp had been captured by a commercial fisher above O'Brien Lock and Dam in Lake Calumet.

tributaries listed include the Rifle and Saginaw rivers. The Belle and Black rivers, tributaries to the St. Clair River, are also listed. The Raisin River is the only Lake Erie tributary listed for Michigan, and only one Lake Superior tributary, the Ontonagon River, is listed. Although these waters would certainly be at high risk, we caution that there are many other waters in Michigan that could also potentially support populations of bighead and silver carps. In particular, lakes adjacent to Lake Michigan, including the drowned rivermouth lakes (e.g., Muskegon Lake, White Lake, Pere Marquette Lake, Manistee Lake, Betsie Bay) might be vulnerable. Green Bay, including Big and Little bays de Noc, might also host populations of bighead and silver carps. Saginaw Bay, Lake St. Clair, and western Lake Erie – very heavily fished waters with abundant populations of native Michigan fishes – are also areas that would be at great risk if bighead and silver carps were introduced to the Great Lakes.

In Michigan, the sportfishing industry is very economically important. Sport and commercial fishing generate an estimated \$7 billion annually in the Great Lakes (Hansen 2010). In particular, there are many local economies in Michigan that are based almost entirely upon local sport fisheries. While it is impossible to predict exactly which local sport fisheries would be affected and to what extent, it is certain that if bighead and silver carps are introduced to Michigan waters, they will influence local sport fisheries and therefore local economies. It is also possible that they would severely affect regional fisheries and regional economies such as the Lake Michigan Chinook salmon fishery, the Saginaw Bay walleye fishery, or the Lake St. Clair yellow perch fishery.

Because of their jumping nature, silver carp pose a safety threat to boaters on waters with large populations of silver carp. When disturbed by boat motors, silver carp jump out of the water (Kolar et al. 2007) to a height of four or five feet. Many boaters in other states have been hit by jumping silver carp, and a few have even been seriously injured (Kolar et al. 2007). Water skiers are also at risk to injury from jumping silver carp.

For these reasons, it is absolutely critical that bighead and silver carps not be allowed into Michigan waters. Once they are established and begin to reproduce, it will be very difficult or impossible to eradicate them. Although techniques and strategies may be found to limit their abundance and influence on other species, these will likely be very costly. For example, the Great Lakes Fishery Commission (GLFC) currently spends nearly \$30 million annually to control sea lamprey, another invasive species, in the Great Lakes (Great Lakes Fishery Commission 2008). Without these control efforts, the sea lamprey would have even more dramatic effects on the sport and commercial fisheries of the Great Lakes. Control efforts for species like bighead and silver carps could potentially be even more difficult and expensive than those for sea lamprey. According to Conover et al. (2007), the economic effects from AIS in the Great Lakes Basin in 2005 totaled around \$5.7 billion. If bighead and silver carps enter the Great Lakes, that figure is certain to increase dramatically, with Michigan facing a disproportionate share of the burden due to the facts that it borders four of the Great Lakes and that these lakes all support economically important fisheries.

Black carp

Due to their current distribution in the United States, the most likely immediate cause of permanent introduction of black carp to Michigan waters would be through interstate fish shipments from southern states. If they did become established in Michigan waters, black carp could pose a major threat to Michigan native mussel populations. Michigan's Wildlife Action Plan (Eagle et al. 2005) indicates that nearly 60% of freshwater mussels are endangered,

threatened, of special concern, or in need of conservation. There is the potential for black carp to further reduce populations of some of these mussel species that are already at risk. In addition, lake sturgeon are listed as a state-threatened species in Michigan (Section 36505 (1a), Part 324, Endangered Species Protection, of Act No. 451 of the Public Acts of 1994; Hay-Chmielewski and Whelan 1997), and significant reductions in mussels and other invertebrates could affect growth and survival of lake sturgeon, as well as other native molluscivores (e.g., freshwater drum, redhorse species; see French 1993). As with bighead and silver carps, black carp would likely be successful in many different waters in Michigan.

Grass carp

The most likely cause of permanent introduction of grass carp to Michigan waters would be from diploid grass carp erroneously stocked in one of Michigan's border waters. Another potential vector would be through interstate fish shipments from southern states. As with bighead, black, and silver carps, grass carp would likely be successful in many different waters in Michigan. Grass carp can affect aquatic ecosystems in a myriad of ways (Cudmore and Mandrak 2004). As herbivores, they have the potential to dramatically affect the abundance and species composition of aquatic macrophytes in a particular waterbody. Removal of vegetation by grass carp can cause an increase in algal blooms and a subsequent increase in turbidity. Other potential influences of grass carp introductions include changes in zooplankton, invertebrate, and fish species composition and abundance (Cudmore and Mandrak 2004). Grass carp can even have negative interactions with some wildlife species, especially waterfowl that also use the aquatic plants preferred by grass carp.

3) POLICY BACKGROUND

Michigan Policy and Legislation

Under the public trust doctrine, Michigan holds all fish that are within the State's jurisdictional waters in trust for the benefit of its citizens. Michigan's obligation to preserve and protect its resources is prescribed by Article 4, § 52 of the Michigan Constitution. This constitutional mandate was reauthorized through Executive Order 2009-45, which established the Michigan Department of Natural Resources and Environment. Protection of the State's natural resources is delegated to the DNRE in the Natural Resources and Environmental Protection Act (NREPA) 451 of 1994. The DNRE Director has the authority to promulgate rules to protect the natural resources of the state of Michigan. Within the State of Michigan, AIS issues related to Asian carps are handled through five primary means: legislative statute, executive orders from the Governor, administrative rules, DNRE Fisheries Orders, and division permitting. Descriptions of the applicable processes are as follows:

The Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended, is the **State legislation** used to protect the environment and natural resources of the state.

Executive Orders are used by the Governor to form committees or produce organizational changes within state agencies. The Office of the Great Lakes (OGL) was created under Section 32903 of NREPA, 1994 PA 451, MCL 324.32903, was subsequently transferred to the Department of Environmental Quality by Executive Order 1995-18, MCL 324.99903, and most recently was transferred to the newly created DNRE under Executive Order 2009-45. This order provides AIS management authority to the DNRE Resource Management Deputy Director and ballast water regulatory authority to the DNRE Water Resource Division.

Administrative Rules have been implemented to prohibit possession of unwanted species and to protect the environment and natural resources of the state. For example, the importation of grass carp or eggs is prohibited without a permit under DNRE Administrative Rules R299.1052 et seq.

DNRE Fisheries Orders are used to implement law, while **divisional permitting** has been implemented to regulate activities not otherwise covered by statute or administrative rules. *In 2003, Fisheries Order 209 was updated, making it illegal to transport or possess live specimens of several species including bighead carp, black carp, grass carp, and silver carp.*

Subsequently, these species were included as prohibited species under the authority of NREPA 1994 PA 451, as amended; Part 413, Transgenic and Nonnative Organisms and accompanying rules. In October 2007, in response to the recent addition of largescale silver carp to the list of injurious species under the Lacey Act (*Federal statute prohibiting trade in wildlife, fish, and plants that have been illegally taken, possessed, transported or sold*), the DNR modified its Fisheries Order (209.07) by adding largescale silver carp to the list of species that may not be possessed or transported alive. Other permitting activities of the state with possible Asian carps implications involve scientific collector's permits (SCP) and public waters stocking permits, both administered by the DNRE Fisheries Division.

Michigan's Authority

Geographic Scope

All fish found in the Great Lakes, bays of the Great Lakes, connecting waters between those lakes, and inland lakes and streams are property of the State of Michigan (Michigan Compiled Laws § 324.47301 and § 324.48702(1)). The goal of our proposed plan is to prevent the introduction of Asian carps into these waters, while recommending communication, assessment, and management strategies for implementation should Asian carps become established in the State. The benefit of implementing this plan is to protect Michigan's fish, aquatic ecosystems, water-based recreation, and other benefits our waters provide Michigan citizens. In 2003, Public Act 270 amended NREPA to create Part 413. Under the authority of Part 413, Transgenic and Nonnative Organisms and accompanying rules, a person shall not knowingly possess or introduce a live organism if the organism is a prohibited or restricted species. Part 413 also establishes penalties for violations of the statute. In 2004, the list of prohibited species under Part 413 was expanded to include bighead carp, black carp, grass carp, and silver carp.

Management Scope

Within Michigan, both the DNRE and MDA have regulatory authority related to management of Asian carps. The DNRE Director has authority to regulate the taking or killing of fish, animals, or game birds for protection or preservation purposes, and may promulgate rules and orders as necessary under PA 451, Part 411, § 324.41102. The DNRE has the authority under Section 45906 of Part 459 to prohibit or restrict the importation of any species of game fish or other fish if the importation of that species would endanger the public fishery resources. Stocking of fish into the public waters of the State is prohibited without an approved permit under the authority of Section 48735 of Part 487. A person shall not plant any spawn, fry, or fish of any kind in any of the public waters of this State or any other waters under the jurisdiction of this State without first obtaining a permit from the Department that states the species, number, and approximate size or age of the spawn, fry, or fish to be planted and the name and location of the waters where the spawn, fry, or fish shall be planted. Exceptions may be obtained with a permit only for fish culture, scientific investigation, or for the protection of the inland waters from ecological damage or imbalance under the authority of Section 48735. Taking of baitfish from the State's waters for commercial use, or importation of baitfish for commercial use requires a baitfish license administered by DNRE Fisheries Division pursuant to Sections 48728 – 48732 of Part 487. A person shall not take or possess minnows, wigglers, or crayfish for commercial purposes from any of the waters over which this State has jurisdiction; import minnows, wigglers, or crayfish for commercial purposes from outside of this State; or transport minnows, wigglers, or crayfish without having first procured a license as provided in section 48732. Exceptions are provided for individual anglers that possess a valid fishing license to obtain bait for personal use. All live fish sales under the jurisdiction of DNRE must now comply with the Fish Disease Control Order (FO 245). Restrictions pertaining to this order include regulation by management area (e.g., viral hemorrhagic septicemia (VHS) positive, surveillance, and pathogen free zones), list of prohibited species for susceptibility to pathogens of concern, facility certification and permitting, transportation and use of baitfish for recreational fishing, and stocking certified disease free live fish or roe in public waters.

Administrative responsibility for these sections falls to DNRE Fisheries Division, as does the conservation, protection, management, use, and enjoyment of Michigan's aquatic resources. To complement these efforts, the DNRE administers (through Water Resource Division) an AIS "core program", to identify and block pathways used by aquatic invasive species to enter the

state or spread within the state. A concurrent goal is to prevent establishment of new AIS that have been able to enter Michigan waters. The goals are accomplished through regulations, education, research, coordination, early detection, rapid response, and assessment as implemented under Michigan's Aquatic Nuisance Species State Management Plan (Office of the Great Lakes 2002). This plan was originally developed in 1996 under the auspices of the National Invasive Species Act, and outlines strategies for AIS management, prevention, and control. *Core Program* participants include staff from each of the four divisions in the Resource Management Bureau, plus staff in the Office of the Great Lakes, the Michigan Department of Agriculture, and the Recreation Division in the DNRE Stewardship Bureau. These staff members participate in the AIS prevention program, provide overall coordination for the program and coordinator the program within their respective divisions/departments. They report through their division/department management who have accountability for the AIS program.

The MDA regulates the private aquaculture industry and aquarium/pet trade, where production of aquaculture species must be from an approved list of species established by the Aquaculture Development Act (199 of 1996). Any movement, importing, or exporting of aquaculture species shall be in compliance the Aquaculture Development Act. Aquaculture species are qualified for inclusion on the list of approved species if they occur naturally within the waters of the State, have been naturalized within waters of the State, could not perpetuate in the waters of the State, or are held in confinement facilities for purposes of research. Possession of aquaculture species that are prohibited under NREPA, Act No. 451 of the Public Acts of 1994, being sections 324.101 to 324.90106 of the Michigan Compiled Laws, are prohibited for aquaculture or aquaculture research.

Great Lakes Basin Authorities

Management Authority

There are numerous jurisdictions, authorities, and roles of agencies and governmental units involved with Asian carps issues in the Great Lakes Basin. For a list of agencies working on the Chicago Sanitary and Ship Canal to prevent the introduction of Asian carps into the Great Lakes, please refer to Section 1.3 of the Asian Carp Control Strategy Framework (Asian Carp Workgroup, May 2010). Similarly, a number of federal laws and regulations exist with the purpose of preventing and managing AIS in areas under federal authority. These laws are briefly described below.

Implemented in 1990, NANPCA is the federal legislation established for the prevention and control of aquatic nuisance species. This Act was reauthorized in 1996 as the National Aquatic Invasive Species Act that mandated regulations to prevent the introduction and spread of AIS into the Great Lakes through ballast water. The national Aquatic Nuisance Species Task Force was established under Section 1201 of NANPCA to coordinate governmental efforts in the United States with those of the private sector and other North American interests. Great Lakes Basin and St. Lawrence River regional coordination is addressed under Section 1203 of NANPCA, which calls upon the Great Lakes Commission to coordinate and advise activities. The Great Lakes Commission coordinates the Great Lakes Panel on Aquatic Nuisance Species. The Panel has worked to coordinate exotic species program activities in the region and make recommendations to the national Aquatic Nuisance Species Task Force.

The National Health Protection Act of 2004 authorizes the U.S. Secretary of Agriculture to prohibit or restrict importation and movement of any animal to prevent the introduction or dissemination of any pest or disease into or within the United States. This law is the primary authorization which allows the Animal Plant Health and Inspection Service (APHIS) to regulate movement and interstate transport of infected species. This law allowed the DNRE to develop Fisheries Order 245 regulating VHS virus-susceptible fish and inspection of baitfish. The Lacey Act includes federal mandates that restrict fish movements due to transmission of diseases and transportation or shipment of certain plants and animals considered as injurious or nonnative species. In 2007, the U.S. Fish and Wildlife Service (USFWS) added all forms of live black, silver, and largescale silver carps to the list of injurious wildlife under the Lacey Act. In addition, the USFWS petitioned to add bighead carp and are evaluating this species to make specific recommendations. The Water Resource Development Act of 2007 authorizes the upgrade, operation, and maintenance of electrical barrier I and the construction of electrical barrier II in the Chicago Sanitary and Ship Canal. In addition this Act authorizes monetary support for a feasibility study to investigate the range of options and technologies available to prevent the spread of aquatic invasive species between the Great Lakes and Mississippi River basins.

Management Strategies

The USFWS Midwest Region coordinates implementation of the “Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States” (Conover et al. 2007). This plan was approved by the Aquatic Nuisance Species Task Force in 2007 and includes 7 goals, 48 strategies and 131 recommendations for protecting the United States from the introduction of Asian carps. Many of these recommendations fit well with ongoing efforts in the Great Lakes.

Although not intended to be an exhaustive list or an endorsement of strategies, ongoing efforts in the Great Lakes Basin to reduce the threat of Asian carps include:

- Two electrical barriers in the Chicago Sanitary and Ship Canal to prevent movement into Lake Michigan, with a third barrier proposed for 2010. These barriers are operated and maintained by the U.S. Army Corps of Engineers (USACOE).
- Support for ecological separation, to make it impossible for species to move to and from the Mississippi River to the Great Lakes Basin. From GLFC (2010); “Ecological separation is a relatively simple concept: it means taking steps so that no interbasin transfer of aquatic organisms can occur. It means preventing the movement of all aquatic organisms – at all life stages – between the watersheds. Ecological separation, by definition, means 100% effectiveness in blocking species migration via the waterway.” The effects of ecological separation are additionally discussed in reports by Brammeier et al. (2008) and Taylor and Roach (2009).
- Construction of barriers to prevent movement of Asian carps from the Chicago Sanitary and Ship Canal into the Des Plains River during times of flooding (USACOE 2010).
- Environmental DNA surveillance by the USACOE and Center for Aquatic Conservation, University of Notre Dame (CAC) in 2009-2010 to document the presence of Asian carps upstream of Chicago Sanitary and Ship Canal electrical barriers.
- Rotenone application to the Chicago Sanitary and Ship Canal in December 2009 while electrical barriers were down for upgrade and maintenance.

- Several legislative efforts to strengthen restrictions on possession and prevent movement of Asian carps; for example, the CARP Act (Close All Routes and Prevent Asian Carp Today) introduced by U.S. Congressman David Camp (R-MI) and U.S. Senator Debbie Stabenow (D-MI).

4) MANAGEMENT ACTIONS

Goal I: *Prevent the accidental or deliberate introduction of bighead, black, grass, and silver carps in Michigan*

Problem Statement

It is well-documented that, once introduced, AIS are difficult to eradicate and expensive to manage (Fuller et al. 1999, Lodge et al. 2006). As mentioned previously, life history traits of Asian carps make them well-suited for establishment in Michigan, thereby increasing the risk of ecological, recreational, and economic effects. Preventing establishment of Asian carps in Michigan's waters is the principal method available to avoid these risks and maintain the public's ability to use and enjoy our waters.

Similar to sea lamprey, once established in the Great Lakes, it is likely Asian carps would become a permanent component of the fish community. In fact, the lessons learned from sea lamprey tell us that an invasive species can not only cause ecological and economic damage, but also result in expensive and difficult control efforts. Control methods available for Asian carps, for example piscicides and harvest, may have limited effectiveness. According to Hansen (2010), the paucity of control options is a strong motivator for prevention and this message has been repeated by the GLFC for more than a decade. It is clearly more efficient and inexpensive to prevent an invasive species rather than pursue attempts to control or eradicate.

Many of the efforts aimed at preventing Asian carps from entering the Great Lakes, such as electrical barriers in the Chicago Sanitary and Ship Canal or ecological separation of the Mississippi River and the Great Lakes, are not under the direct authority of the DNRE. However, there are several things that we can do and several recommendations we can make to reduce the likelihood of Asian carps entering Michigan's waters. For example, activities related to wild-caught baitfish were ranked by the Asian Carp Working Group (Conover et al. 2007) as the highest risk for introducing Asian carps into new waters, since live fish can easily be released by anglers and commercial bait dealers. Furthermore, juvenile Asian carps such as bighead and silver carps are similar in appearance to native baitfish (e.g., gizzard shad), thus increasing the likelihood that they could be accidentally introduced. One pathway of concern is the collection and transportation of juvenile Asian carps during permitted bait harvesting efforts, whether wild-caught or farm-raised bait. Another pathway for introduction of Asian carps is the common practice by anglers to discard unused bait into the water. The risk of introducing Asian carps through activities related to baitfish is great and warrants immediate action.

Several pathways exist to inadvertently and intentionally introduce adult Asian carps into Michigan's waters, including fish stocking. For example, fish are commonly transported throughout the state for stocking purposes and it is not unheard of for non-target species to be accidentally included in shipments. Bighead, silver, and grass carps are sometimes stocked in catfish ponds to remove algae and suspended matter and, therefore, could unintentionally be included during harvesting operations. Accidental or intentional introduction by commercial or recreational fishers who have incidental catches of Asian carps that are either taken to markets for live sale or moved into other waters are other pathways for introduction of Asian carps. It is also possible that Asian carps may be introduced through the cultural practice of prayer animal release (Severinghaus and Chi 1999). The pathways for introduction of live, adult Asian carps

vary widely and will require a comprehensive approach targeted at regulatory reform and improved communication with stakeholders.

Many of the strategic actions selected to address the goal of prevention are taken from recommendations made by the Asian Carp Working Group (Conover et al. 2007). After considering the risks, costs, and benefits, four strategies were selected for implementation in Michigan's waters.

Strategic Actions

1. Prevent transport and release or improper disposal of Asian carps that may be intermixed with baitfish

Tasks

a. Improve effectiveness of regulations, laws, and authorities

Although regulations exist for transportation and importation of live fish, including compliance with an approved list of species per the Aquaculture Development Act (199 of 1996), enforcement is not common practice. At this time, importation of baitfish is limited to species that are native or naturalized to Michigan, fish must be certified as VHS free, and MDA requires prior notification from distributors before entering the state. In a similar effort, baitfish could be certified as containing no Asian carps and testing could be accomplished at aquaculture facilities using eDNA surveillance. To provide additional protection, we recommend that shipments of all live baitfish be certified as containing no AIS, including Asian carps.

Authorization exists to regulate the baitfish industry (see Section 3; Policy Background) and this authorization should be evaluated for improvements. For example, the DNRE issues limited retail minnow dealer's licenses, wholesale minnow dealer's licenses, and minnow catcher's licenses upon receipt of application and fee. With these licenses, oversight is limited to reviewing the previous year's harvest report when license renewals are submitted. To improve this process, we recommend that the DNRE Fisheries Division Aquatic Species and Regulatory Affairs (ASRA) Unit increase administrative oversight of commercial bait harvest license holders, including verification of new regulatory requirements such as certification (Asian carps-free and HACCP) and compliance with prior notification.

As another step to prevent the introduction of Asian carps, we recommend HACCP certification for all commercial bait license holders (see Goal V, Strategy 1). The HACCP planning process provides a systematic method to reduce the spread of Asian carps and its required preventative measures would reduce risks associated with baitfish harvest. We understand that the Michigan Bait Dealers Association has hosted HACCP certification workshops for their membership and a number of baitfish dealers have voluntarily developed HACCP plans related to VHS. Without HACCP planning and prevention methods, fish shipments are at greater risk of including Asian carps as non-target species.

Although we discussed the possibility of new regulations or laws to prevent harvest of wild baitfish, we believe this is an extreme option and do not recommend it at this time. Michigan's baitfish industry depends on wild caught fish for approximately 70% of its business, according to the Michigan Bait Dealers Association. Any efforts to curtail this industry must be carefully considered. However, if efforts aimed at oversight of the baitfish industry and HACCP

certification are shown to be ineffective at preventing the introduction or spread of Asian carps, we recommend consideration of new regulations or laws related to the harvest of wild baitfish.

We should also improve our current regulations to require anglers to properly dispose of all unwanted live bait. Current regulations that relate to baitfish disposal are fish stocking into the public waters of the State of Michigan with an approved permit under authority of Section 48735 of Part 487, Sport Fishing, of Act 451, P.A. 1994, as amended, and restrictions on the release of live baitfish under Fisheries Order 245 to control the spread of fish disease, particularly VHS. Neither of these regulations communicates an obvious or enforceable message that all anglers are responsible for properly disposing of unwanted live bait. The release of live bait into Michigan's public waters should be prohibited, regardless of VHS status, and this ban should be clearly advertised to the public. Proper disposal of unwanted live bait would reduce the risk of inadvertently releasing Asian carps and other AIS, as well as reduce the spread of disease.

b. Increase inspection of baitfish distributors and hauling equipment

We understand that some effort is currently expended towards inspecting baitfish distributors and hauling tanks; however, this effort may be improved since it is informal and performed on an inconsistent basis throughout the State. In addition to prior notification by distributors before entering the State, we recommend routine inspection of baitfish distributors and hauling equipment, including inspection of the water used during transportation, to prevent introduction of Asian carps or their eggs and larvae. We also recommend that all baitfish be certified as containing no AIS or Asian carps prior to being stocked. This task will require training for those conducting inspections (e.g.; DNRE Law Enforcement Division, MDA).

c. Improve communication with stakeholders on both existing regulations and the negative effects of Asian carps

We recognize that stakeholder cooperation related to prevention of Asian carps introduction is dependent upon stakeholders understanding the pathways for introduction and the effects on existing aquatic communities and economies. We recommend increased communication with stakeholders, including the commercial baitfish industry and recreational anglers, to reduce the risk of accidentally introducing Asian carps (see Goal II).

2. Control ongoing and permitted fish stocking efforts to prevent inadvertent introduction of Asian carps

Tasks

a. Improve effectiveness of existing regulations, laws, and authorities

As mentioned previously, regulations exist for transportation and importation of live fish (Section 3; Policy Background) and penalties are established for knowingly possessing or introducing a live prohibited or restricted species such as Asian carps (NREPA PA 451, Part 413). We recommend improved enforcement of this Act to prevent the accidental release of Asian carps that may be intermixed with species intended for stocking, such as channel catfish. In addition, all shipments of live fish should be certified as containing no AIS. As additional steps to prevent the introduction of Asian carps by commercial distributors, we recommend compliance with HACCP certification and prior notification to MDA before distributors enter the state.

b. Increase inspection of fish distributors and hauling equipment

Similar to baitfish, we understand that some effort is currently expended towards inspecting fish distributors and hauling tanks on an informal and inconsistent basis. We recommend routine inspection of fish distributors and hauling equipment, including inspection of the water used during transportation, to prevent introduction of Asian carps or their eggs and larvae. This task will require training for those conducting inspections (e.g., DNRE Law Enforcement Division).

c. Improve communication with stakeholders and regulatory partners

Efforts should be undertaken to improve communication with stakeholders, including fish distributors and commercial or recreational fishers, to reduce the risk of accidental introduction (see Goal II). We also recommend improved coordination among DNRE divisions, and with MDA, regarding related fish stocking authorities.

3. Prohibit import, possession, sale, purchase, and intentional introduction of Asian carps

Tasks

a. Improve effectiveness of existing regulations, laws, and authorities

Again, regulations exist for transportation and importation of live fish, including compliance with an approved list of species per the Aquaculture Development Act (199 of 1996) and penalties are established for knowingly possessing or introducing a live prohibited or restricted species such as Asian carps (NREPA PA 451, Part 413). In addition, ballast-water discharges by ocean-going vessels (which could also lead to the introduction of Asian carps; see Mills et al. 1993) are reviewed and permitted through the DNRE Water Resource Division. The effectiveness of these laws in preventing intentional introductions of live, adult Asian carps should be routinely reviewed by DNRE and MDA for improvement, or by an Asian Carp Task Group (once this is established – see Goal II, Strategy 6). One recommendation is to certify all shipments of live fish as containing no AIS.

b. Increase inspection of fish distributors and hauling equipment

We recommend routine inspection of fish distributors and hauling equipment, including inspection of the water used during transportation, to prevent introduction of Asian carps or their eggs and larvae. This task will require training for those conducting inspections (e.g., DNRE Law Enforcement Division).

c. Improve communication with stakeholders and regulatory partners

Asian carps may be intentionally introduced by fish distributors, commercial fishers, or recreational anglers who take live Asian carps to markets for sale, move them into other waters, or use them for ceremonial purposes. Efforts should be taken to improve communication with stakeholders (see Goal II) so that negative effects of introduction are well understood. We also recommend improved coordination among the DNRE and MDA regarding related fish stocking authorities.

4. Work with other agencies and partners to prevent introduction or range expansion of Asian carps in situations where we have common interests or existing cooperative agreements for management

According to Conover et al. (2007), coordination among states and other resource agency partners will allow for the most effective management and control of Asian carps. Coordination by partners including Canada, federal agencies, state agencies, and tribes will depend on both the issue and existing authority. Although coordination is already occurring, for example the December 2009 rotenone efforts in the Chicago Sanitary and Ship Canal, there are opportunities for coordination to proceed in a more formal manner. According to the Asian Carp Workgroup (2010), cooperation will result in innovation and effective ideas, more solid stakeholder commitments, and a better chance at lowering the risk of invasion. This strategy also echoes the recommendations made in the Michigan Aquatic Nuisance Species State Management Plan (Office of the Great Lakes 2002) to increase coordination and cooperation to prevent and control the spread of AIS. To effectively accomplish this strategy we recommend the following implementation efforts:

- continue to improve communication among partners to provide consistency among appropriate authorities;
- explore options for participation on Asian Carp Regional Coordination Committee (<http://www.asiancarp.org/about.asp>);
- provide unified support for actions that help prevent the spread of Asian carps, including ecological separation of the Mississippi River and the Great Lakes;
- implement, at a minimum, an annual review of the status of Asian carps in Michigan's jurisdictional waters, including geographic distribution; and
- coordinate with border water states that presently allow stocking of grass carp (i.e., Indiana and Ohio) to prevent infestation of Michigan's waters.

Goal II: Effectively share information to improve management and control of bighead, black, grass, and silver carps in Michigan

Problem Statement

It is well understood that one of the primary lines of defense against establishment of Asian carps in Michigan is a well-informed public. According to Conover et al. (2007), stakeholders should possess information to take action and help prevent unauthorized releases of Asian carps. A public education campaign is declared by Kolar et al. (2007) as the only tool available for immediate use to control the spread of Asian carps. We recommend sharing of information as an urgent and priority action to improve effective management and control of bighead, black, grass, and silver carps in Michigan.

Like our strategies for prevention, many of the strategic actions selected to address the goal of communication are taken from recommendations made by the Asian Carp Working Group (Conover et al. 2007). After considering the risks, costs, and benefits, we selected six strategies for implementation in Michigan's waters. All of these strategies will require the involvement, leadership, and cooperation of DNRE Media and Communications staff to ensure the Department successfully reaches our target audiences with the appropriate messages. While these strategies will require additional commitment from DNRE staff both initially to develop

information and over the long term to keep the public informed of current developments, most information can be made available via the internet to keep implementation costs low. In addition to utilizing the DNRE web site, information should be highlighted in our annual Fishing Guide, shared through printed materials at license vendors (e.g., posters), and made known through signage at boat access sites. According to Asian Carp Workgroup (2010), a Strategic Communication Plan is being developed and information will be shared on <http://www.asiancarp.org/>; therefore, the first step in developing DNRE communication materials should be a review of available information to avoid redundant efforts. Our first five communication strategies engage the public (e.g., recreational and commercial fishers, fish distributors, and baitfish harvesters), and the final strategy involves communication between DNRE and MDA.

Strategic Actions

1. Develop educational materials related to the identification of Asian carps

To improve the public's skills in properly identifying Asian carps, we propose development of an information module that clearly explains and displays identifying characteristics for all life stages. From a quick internet search, it appears that some information already exists for identifying adult Asian carps that could be used or improved upon, for example the Mississippi River Basin Regional Panel of the Aquatic Nuisance Species Task Force's identification key (<http://www.asiancarp.org/idkeys.asp>) and Illinois-Indiana Sea Grant posters and WATCH cards (<http://www.iisgcp.org/AsianCarp/>). Insufficient information is readily available to help distinguish between juvenile Asian carps and the native baitfish they closely resemble (Conover et al. 2007). Since one of the main pathways of concern for introduction of Asian carps is through baitfish handling, additional effort will need to be expended to provide a juvenile identification key that is useful to the public. If possible, fish mounts or reproductions should be obtained for both juvenile and adult life stages of the Asian carp species. These mounts can be displayed at DNRE offices and used as an educational tool at various events and shows. By correctly identifying Asian carps, the public will be able to assist in the prevention of unauthorized releases and improve detection efforts (Conover et al. 2007).

2. Develop educational materials describing the potential negative effects of Asian carps and methods to prevent their introduction

This strategic action is similar in scope to the recommendation of Glassner-Shwayder (1996) to inform and educate the public on the negative effects caused by the spread of AIS and make prevention of introduction a priority. Similarly, Michigan's Aquatic Nuisance Species State Management Plan (Office of the Great Lakes 2002) recommends implementation of educational activities to prevent the introduction and dispersal of AIS. Until the public understands the importance of preventing the introduction or spread of Asian carps, it will be difficult to change potentially risky behaviors. We need to communicate to the public the strategies outlined in Section 4, Goal 1 (Prevention) to further avoid the introduction or spread of Asian carps in Michigan.

Information on the negative effects of Asian carps is already provided on the DNRE web site, including frequently asked questions http://www.michigan.gov/dnr/0,1607,7-153-10364_52261_54896---,00.html, and this information should be reviewed by the Media and Communications Office to make sure it is accurate and current. In general, a wealth of

information already exists on the web and should be considered for its usefulness including Minnesota DNR <http://www.dnr.state.mn.us/invasives/aquaticanimals/asiancarp/index.html>, Wisconsin DNR http://dnr.wi.gov/invasives/fact/asian_carp.htm, and information managed in cooperation with the USFWS <http://asiancarp.org/>.

3. Develop educational materials describing regulations pertinent to preventing the introduction of Asian carps

The regulations related to Asian carps in Michigan may not be well understood by the public due, in part, to different regulations in neighboring states and the overwhelming information presented by the media. To reduce confusion and ensure the public has the most accurate facts, an information module should be developed that explains Michigan's regulations for Asian carps. By publicizing and explaining our regulations, the public will be more capable of preventing the spread of Asian carps (Glassner-Shwayder 1996).

4. Develop educational materials describing human health and safety issues related to establishment of Asian carps

Asian carps may negatively influence human health or safety either through physical injury caused by jumping (i.e., silver carp) or through human consumption of potentially contaminated fish.

Silver carp are known to leap from the water in response to vibrations produce from outboard motors and there are numerous reports of silver carp not only injuring boaters and water skiers, but also boating equipment (Kolar et al. 2007). Illinois-Indiana Sea Grant has developed a handout with suggestions for protecting people and equipment from damage that may be caused by Asian carps while boating (<http://www.iisgcp.org/AsianCarp/flyingfish.pdf>). If silver carp establish themselves in Michigan's waters, information will need to be shared on physical risks caused by jumping fish and any strategies for avoiding these risks.

Marketing and consumption of Asian carps is often promoted as a management strategy (see Kolar et al. 2007). Currently, a market exists for Asian carps, primarily in Asian-American communities in New York, Chicago, and California. The strategy of encouraging recreational and commercial harvest of Asian carps is discussed further under Goal V, Strategic Action 3 of this report. Concurrent with promotion of recreational and commercial fishing opportunities, information should be shared with the public on the contaminant burden of Asian carps. According to the Asian Carp Regional Coordinating Committee website (<http://www.asiancarp.org/faq.asp#13>) "Asian carps are low on the food chain, fast growing, low in fat in the filets, and they are not usually bottom feeders, all properties of fishes that are lower in contaminants. USGS and the Missouri Department of Conservation have jointly produced data on Missouri River fishes that have shown bighead carps to be generally low in contaminants (lower in contaminants than flathead catfish and common carp from the same water). Nevertheless, one should remain aware of advisories on particular waters." The collection and publication of contaminant data will need to be coordinated among DNRE, MDA, and the Michigan Department of Community Health (MDCH) if Asian carps become established in Michigan's waters.

5. Effectively communicate with the public regarding Asian carps developments and our response strategies

The aim of this strategy is to keep the public well informed on the current status of Asian carps and the DNRE response. Press releases, social media, and the DNRE web site should be used to keep the public up to date. With this strategy, we recommend development of methods (e.g., web based instructions, contact with local field staff) to allow the public to report sightings of Asian carps to the DNRE, similar to reporting of fish kills. Possible reporting options include use of the existing Report All Poaching (RAP) toll-free, 24-hour law enforcement hotline, and use of digital photos or frozen specimens for species verification. This reporting mechanism, if implemented properly, will allow the public to assist DNRE staff by sharing observations from Michigan's multitude of waters (see Goal III, Strategy 2 – detection using an informed public). We recognize that there is the potential for considerable time to be spent addressing false reports of Asian carps, yet even with this potential downside there is a tremendous opportunity for the public to assist us in the early detection and tracking of Asian carps. Therefore, we will need to develop this recommendation carefully and do our best to make sure the public has all the needed tools for proper identification of Asian carps (see Goal II, Strategy 1), and an understanding of the areas of concern for detection. As stated by Conover et al. (2007), public assistance with the monitoring of Asian carps is critical for successful management of these species.

Communication tools for this strategy include:

- Press releases
- Social media
 - Use Facebook to inform public on current events and answer questions
 - Use Twitter to announce press releases
- Provide web based information
 - Minnesota DNR web site, which includes link for public to report sightings <http://www.dnr.state.mn.us/invasives/aquaticanimals/asiancarp/index.html>
 - Wisconsin DNR web site, which includes information on public reporting and verification of sightings http://dnr.wi.gov/invasives/fact/asian_carp.htm
 - Indiana DNR web material, which includes information on bighead carp and on how to report sightings http://www.in.gov/dnr/files/BIGHEAD_CARP.pdf
 - Asian Carp Regional Coordinating Committee web site, which includes information for the public on "How to Help" <http://asiancarp.org/help.asp>

6. Develop DNRE and MDA Asian Carps Task Group and communication system

This strategy echoes the recommendations made by Michigan's Aquatic Nuisance Species State Management Plan (Office of the Great Lakes 2002) to increase coordination and cooperation to prevent and control the spread of AIS. To effectively accomplish this strategy, we recommend identification of representatives to participate on Michigan's Asian Carps Task Group, including State of Michigan employees from DNRE Fisheries Division, Water Resource Division, OGL, Wildlife Division, Law Enforcement Division, Media and Communications Office, and MDA. There is an urgent need to establish this task group, to: implement a public education and communication plan (Goal II), evaluate the existing State of Michigan regulatory framework and potential regulatory changes (Goal I), investigate and implement (as appropriate) new technologies (e.g.; eDNA, pheromone attractants, deterrent technologies) for containing and managing Asian carps (Goal V, Strategy 6), and seek sources of additional funding to implement

priority strategies. Ultimately, these efforts will likely be integrated with those of the AIS Core Program, coordinated by the Water Resource Division.

Goal III: Detect the presence of bighead, black, grass, and silver carps in Michigan

Problem Statement

Grass carp have been occasionally taken from Michigan waters for several decades, although they have not yet established a permanent population. Bighead and silver carps may be on the verge of entering Lake Michigan through the Chicago Waterway and Calumet River systems. If bighead and silver carps do enter Lake Michigan, it may then be possible for them to also invade many other waters of Michigan. Unless they are present in great numbers, however, it can be very difficult to detect the presence of Asian carps using traditional fisheries survey techniques (David Lodge, University of Notre Dame CAC, personal communication). Also, Michigan has nearly 4,000 miles of Great Lakes coastline, 36,000 miles of rivers, and over 11,000 inland lakes. Therefore, detecting the presence of Asian carps in Michigan's waters will be very difficult, particularly during the initial invasion stage when their population levels are low.

Strategic Actions

Many of the strategic actions selected to address the goal of prevention are taken from recommendations made by the Asian Carp Working Group (Conover et al. 2007). After considering the risks, costs, and benefits, five strategies for detecting Asian carps were selected for implementation in Michigan's waters.

1. Implement an eDNA surveillance strategy for Michigan waters, based on Asian carps distribution and likely risk to Michigan waters

Environmental DNA surveillance is a technique by which the presence of aquatic organisms can be detected by collecting water samples and testing them for the presence of DNA of the target species (Lodge 2010). Compared to traditional fisheries survey techniques such as netting or electrofishing, it can be more effective in determining the presence of the target species in large geographical areas. Although eDNA surveillance does confirm the presence of a particular species, it is inferior to traditional fisheries sampling in that it does not provide any further information on the target species beyond simple presence. Despite this, eDNA surveillance appears to be a very powerful tool for tracking the presence of Asian carps. Presently, eDNA surveillance is being conducted for bighead and silver carps in waters near Chicago, Illinois, and work to implement an eDNA surveillance program in Michigan waters began in September 2010. Researchers from the CAC at the University of Notre Dame are leading these efforts, with funding provided through the Great Lakes Restoration Initiative (GLRI; see http://edna.nd.edu/Environmental_DNA_at_ND/Home.html). Ultimate goals of this study are to expand surveillance to all of the Great Lakes and connected waters, and to expand eDNA capabilities to include grass and black carps (among other species).

Environmental DNA surveillance has confirmed the presence of silver carp in Lake Michigan at one location in the Chicago area. Also, as of April 2010, eDNA surveillance confirmed the presence of silver carp in the Chicago Waterway System at seven different locations upstream of the electric barrier at Romeoville, and bighead carp were confirmed at three different locations

upstream of the barrier (Lodge 2010). Thus it is entirely possible that bighead carp, in addition to silver carp, have entered Lake Michigan. Both species are quite capable of swimming long distances (Conover et al. 2007) and it is entirely possible that bighead and silver carps may enter Michigan's waters in the near future, if they have not done so already.

While traditional fisheries surveys may lead to the discovery of bighead and silver carps in Michigan's waters, detection via traditional surveys is not likely to occur until Asian carps are present in large numbers. Also, DNRE does not have the personnel that would be necessary to initiate a large-scale survey using traditional fisheries techniques to search for Asian carps in all waters where they might become present. Therefore, it is imperative that an eDNA surveillance regime be instituted for Michigan waters. Waters to be sampled initially should be those with the highest risk of invasion and colonization by Asian carps (Note: a preliminary eDNA survey was recently conducted in the St. Joseph and Galien Rivers in southwest Michigan). If and when Asian carps begin to show up in Michigan's waters, eDNA surveillance priorities should be adjusted accordingly.

Currently, DNRE does not possess any laboratory capability to properly analyze water samples collected during eDNA surveillance. The only regional facility that presently has the capability is the CAC at the University of Notre Dame. If DNRE conducted its own eDNA surveillance (i.e., water sample collection), the CAC might be able to analyze the samples; the cost for analysis could be as high as \$70 per sample. An appropriate eDNA surveillance regime for the St. Joseph River would require up to 100 samples taken between Berrien Springs Dam and Lake Michigan per sampling effort, with as many as three different sampling efforts conducted in one year (Lindsay Chadderton, The Nature Conservancy, personal communication). Therefore, it might cost as much as \$21,000 to appropriately sample just one river. Another potential option would be to develop the appropriate laboratory facilities in Michigan. We estimate that it would cost roughly \$500,000 to develop a laboratory with eDNA capabilities, with an additional \$200,000 required annually to operate the facility.

Following are the areas that we should consider to be priorities for eDNA surveillance activities in 2010:

- Lake Michigan – sites near New Buffalo, St. Joseph, South Haven, Saugatuck, and Grand Haven;
- St. Joseph River, between Berrien Springs Dam and St. Joseph;
- Grand River, between Grand Rapids Sixth Street Dam and Grand Haven, including Spring Lake;
- Galien River, from the confluence of the North and South Branches downstream to New Buffalo; and
- Lake Erie, near Monroe.

The waters of Lake Michigan listed above should be high priorities for eDNA surveillance because they are in the closest proximity to the likely entry point of Chicago. Lake Erie should be a high priority because bighead carp have been previously captured from Lake Erie waters, although it is believed that they were isolated individuals and not part of a self-sustaining population (see Morrison et al. 2004). The goal of that eDNA surveillance effort would be to confirm that hypothesis.

If Asian carps are confirmed in the Michigan's waters of Lake Michigan or one of its connecting waters, then eDNA surveillance should be expanded to cover other vulnerable waters, especially in waters that are closest in proximity to the confirmed location. In particular, other tributaries – including the Kalamazoo, Muskegon, Pere Marquette, and Manistee rivers – should be sampled. Drowned rivermouth lakes, including Lake Macatawa, Muskegon Lake, White Lake, Pere Marquette Lake, Manistee Lake, and Betsie Bay should also be sampled, along with Big and Little bays de Noc. The goal of these eDNA surveillance efforts would be to determine which species of Asian carps are present and to what extent they have invaded Michigan waters.

If any of the eDNA surveillance efforts confirm the presence of Asian carps, then fisheries surveys utilizing traditional methods including netting, electrofishing, and possibly acoustics should be designed to determine population levels of Asian carps in the area(s) where they are initially detected. In addition, if Asian carps are documented in Michigan's waters of Lake Michigan or in Michigan's waters of Lake Erie, then eDNA surveillance should begin in the Lake Huron watershed and Lake St. Clair. In particular, the Saginaw River and Saginaw Bay should be sampled, as the Saginaw Bay area represents the best habitat for Asian carps in Michigan's waters of Lake Huron.

2. Use an informed public (including commercial fishers, recreational fishers, and fish distributors) to enhance monitoring for introductions of Asian carps

Because Michigan has 4,000 miles of Great Lakes coastline, 36,000 miles of rivers, and over 11,000 inland lakes, it will be very difficult to detect the presence of Asian carps in Michigan's waters, particularly during the initial invasion stage when their population levels are low. Although eDNA surveillance will help with this effort, it is likely that members of the public – including anglers, charter captains, commercial fishers, riparian landowners, and recreational boaters – will be among the first to sight Asian carps if they do invade Michigan's waters. A method should be developed to allow the public to report sightings of Asian carps to the DNRE; the Anglers Monitoring Network (www.michigan.gov/deq-anglers-monitoring-network) is one existing potential mechanism that could be used to facilitate public reporting. For this action to be successful, it is critical that the public be educated in identification of Asian carps. Strategies for educating members of the public are specifically addressed under Goal II.

3. Develop monitoring network through an expanded scientific collector's permit system

Fisheries Division currently maintains a scientific collector's permit system (see Fisheries Division Policy 01.01.005, "Scientific Collector's Permit Program") by which non-agency (e.g.; universities, non-profits, environmental consulting firms, utility companies) personnel can legally collect fish using fisheries sampling techniques. One condition of all scientific collector's permits issued by DNRE is that the holder must provide a report of all species captured. Therefore, if a permit holder encounters an Asian carp, it will (in theory) be reported to DNRE Fisheries Division. It will be important to provide scientific collector's permit holders with materials to allow them to properly identify Asian carps. Also, they should be advised that if they do capture an Asian carp, they should not return the fish to the water, and they should immediately notify DNRE Fisheries Division.

4. Utilize existing inland and Great Lakes fishery survey efforts to detect the presence of Asian carps

Each year, fisheries crews from DNRE and other agencies (e.g.; USGS, USFWS, USFS) survey many different waters, ranging from small streams to waters of the Great Lakes. The goals of these surveys vary widely, depending on the type of water being sampled and the method being used. All fisheries survey crews, no matter what agency they work for, should be trained in the identification of Asian carps. During these surveys, crew members should be vigilant for the presence of Asian carps. Currently, there are no fisheries surveys being conducted in Michigan that specifically target Asian carps. However, if it is suspected that Asian carps have invaded a particular waterbody (e.g.; public sightings, eDNA surveillance), then fisheries surveys should be designed that specifically target Asian carps in that waterbody.

5. Monitor fish passage systems and weirs to assess the movement and distribution of Asian carps in Michigan rivers

The Grand and St. Joseph Rivers each have multiple fish ladders. Some of these fish ladders have viewing chambers, allowing DNRE staff to identify and count fish passing through the ladders. These will be useful tools in determining whether or not Asian carps are capable of passing through the fish ladders (see, for example, Loch and Bonar 1999). At present, funding is insufficient to allow monitoring at all sites with viewing chambers. Additional funding would be required to insure timely monitoring of sites with fish detection programs. For Asian carps, the highest priority detection sites should be at the most downstream dam on each river (St. Joseph River – Berrien Springs Dam, Grand River – 6th Street Dam). If new fish ladders are constructed on other rivers, consideration should be given to installing viewing chambers so that fish movement, including that of Asian carps, can be monitored at each ladder.

DNRE staff should also be vigilant for Asian carps attempting to ascend rivers which have spawning and harvest weirs. While these facilities are presently run only at certain times of the year, they could potentially be used as surveillance locations on their respective rivers. This would require extra staffing for these locations, and also might require some additional construction and retrofitting. Rivers that currently have spawning and harvest weirs include the Little Manistee, Platte, and Boardman rivers in the Lake Michigan watershed, and also Swan Creek in the Lake Huron watershed.

Goal IV: Gather population level data on Asian carps at areas where they have been detected in Michigan waters; measure response of Michigan fish populations to introduction of Asian carps

Problem Statement

Due to the high cost of conventional assessment programs, and the low likelihood of success of these programs for early detection of Asian carps, we did not include conventional assessment as a primary component of a detection program. However, once Asian carps have been detected in Michigan's waters, assessment will be an important component of a DNRE response strategy. Assessments will address two, linked questions: 1) how many Asian carps are present in the area of concern and 2) how are introduced Asian carps affecting resident fish populations in the area of introduction? Providing answers to these two questions will be critical in formulating a response to an introduction event and in assessing resource damage, should Asian carps become

established. For example, an isolated introduction with no detected reproduction or expansion will likely trigger a different response than detection of a large or rapidly expanding population of Asian carps. Any significant expansion of assessment efforts will be dependent on detected presence of Asian carps in Michigan's waters and identification of an important role for assessment activities in leading to a successful management outcome. Waters vulnerable to invasion by Asian carps for which sufficient baseline data is lacking may also be identified for additional/expanded assessment activities; identification of these waters will be undertaken by the proposed Asian Carps Task Group (and/or AIS Core Program).

The extent and cost of assessment activities will depend on the specifics of each infestation event. For example, the size and complexity of the system invaded, the amount of information already available on the system, the problem of interest, and the possible management responses being considered will all influence the cost of implementing an assessment. While we could not provide specific recommendations for all possible assessment scenarios, we developed estimates for a few likely scenarios and provide these below. These are intended to provide a range of potential assessment costs that are likely to be incurred should Asian carps become established in Michigan's waters.

Costs provided are annual or five-year estimates; these would likely be ongoing if Asian carps become established. An analogy can be drawn to the current assessment programs associated with sea lamprey control in the Great Lakes; our actions under 1b (below) are equivalent to USFWS activities associated with sea lamprey assessment, while actions under 1c are analogous to state and federal agency lake trout assessment activities, designed to evaluate the effects of sea lamprey predation on lake trout and other Great Lakes species of concern. However, this also assumes that we would continue to assess abundance of Asian carps and effects even after they become fully established (should that happen). Some Great Lakes AIS (e.g., round gobies) have prompted no such extensive assessment and control programs.

Strategic Action

1. Implement expanded fisheries surveys in waters where Asian carps have been detected, with survey designs linked to likely management actions in waters of concern.

Tasks

a. Review programmatic, ecological, and social importance of water(s) where Asian carps have been detected; evaluate costs of assessment against information gain and likelihood for management success; if likely benefits justify assessment activities, go to Task b

Upon detection of Asian carps in Michigan's waters, managers with responsibility for those waters and researchers with information pertinent to fisheries management should be convened to evaluate the programmatic, ecological, and social importance of the invaded waters. Questions for consideration include: is this a unique resource that justifies extreme measures for protection? What are the system connections to other waters of concern in Michigan? What are the likely future effects of allowing Asian carps to become resident in these waters? Are fish populations present that a large population of Michigan's public relies upon for recreation, subsistence, or economic livelihood? What is the likelihood of successful management of Asian carps in these waters? If detection was via eDNA surveillance, managers should consider the potential for a "false positive" detection (i.e.; a positive eDNA signal when no Asian carps are

present), and the implications of such a result for future assessment work. Answers to these and similar related questions will be used to evaluate the cost:benefit ratio of implementing assessment activities in the water(s) in question. This evaluation should be completed by the Asian Carp Task Group (see Goal II, Strategy 6).

b. Design surveys to evaluate localized abundance of Asian carps; specific design based on water body characteristics

As indicated above, the extent and cost of assessment activities will depend on the specifics of each infestation event. While we could not provide specific recommendations for all possible assessment scenarios, we developed estimates for a range of likely scenarios involving assessment of Asian carps in Michigan's waters (Table 1). The estimates provided describe single-year surveys in one area, designed to evaluate the current abundance of Asian carps and reproductive status (as applicable) in waters of concern.

c. Design survey to evaluate likely effects of Asian carps on fish populations and parameters of concern identified in Task a, above

As already indicated, the extent and cost of assessment activities will depend on the specifics of each infestation event and the species likely to be affected by invasion of Asian carps. The estimates provided below (Table 2) describe five-year surveys in single areas, designed to evaluate existing fish populations likely to be influenced by Asian carps in waters of concern.

d. Analysis, evaluation, and technology transfer of initial assessments to future areas

Our program evaluation plan (see Section 6) calls for implementation of an adaptive management strategy in addressing introduction of Asian carps into Michigan's waters. An important component of adaptive management will be applying the lessons learned in initial assessment of Asian carps and their effects to future invasion situations. As such, we've specifically included an evaluation task under our "Assessment" goal. Specific tasks in this area will include post-action evaluation of efforts to measure abundance of Asian carps, pre- and post-assessment statistical analysis of assessments of Asian carps effects on Michigan's fish species, and use of these analyses in design of subsequent assessment efforts (see Task a, above).

Goal V: Eradicate, contain, or manage populations of Asian carps if they become established in Michigan

Problem Statement

Experiences attempting to control or eradicate populations of other AIS indicate that these approaches are expensive and require significant long-term dedicated efforts. In most cases, these efforts prove unsuccessful. With these past experiences in mind, our "Eradication" goal follows strategies to detect (as early as possible) introductions of Asian carps into Michigan's waters, and to assess the status of these invasive populations and the potential effects of specific invasion events on important resources and fisheries in Michigan. These prior efforts will directly influence the tactics employed for control of Asian carps, and the extent of those efforts.

We envision several potential pathways for introduction of Asian carps into Michigan's waters. An immediate concern is dispersal of bighead and silver carps from southwest Lake Michigan to Michigan's waters in the eastern part of the lake, including important tributaries and drowned

rivermouth lakes. An equal concern is for the introduction of Asian carps through intentional or unintentional stocking events. Should Asian carps become established in Michigan's waters, their range could expand into new waters. Movement of water, fish, and equipment can be pathways for transfer of Asian carps to new waters, necessitating additional eradication, control, and management efforts.

Managers have a variety of management methods at their disposal; our recommended eradication/control/ management strategies and tactics explicitly recognize the various potential pathways of Asian carps introduction. The actions recommended here are specific to these circumstances, as well as to system characteristics and aquatic species of concern. For example, traditional methods for eradication are often selective for particular fish taxa and size groups. Piscicides may be more efficient for removal of different size groups of Asian carps and for applications in vast habitat types where they occur. Should Asian carps become established, they may be encountered by agencies, universities, tribes, or industries that regularly sample aquatic species and their environment; these encounters may provide some limited opportunities for control. There may be opportunities to encourage commercial and recreational harvest of Asian carp species to reduce recruitment and adult abundance; again, the effectiveness of these efforts may be limited. Because of the limitations inherent in many of the tools currently in our control arsenal, we feel that it will be critically important to monitor and implement new technologies, as they become available.

Should large populations of Asian carps become established in Michigan's waters, they will likely prove extremely difficult if not impossible to eradicate or control. A significant biomass of carps in any of our State's waters will almost certainly have negative ecological effects on most species and habitats in Michigan. For this reason, it is critically important to make every effort to meet our first goal, prevention. However, if Asian carps do reach Michigan's waters, the six strategies (and associated actions) detailed in the following pages are our best recommendations for management. We emphasize here that, *while management will likely be a difficult undertaking, our recommended strategies carry with them a reasonable expectation of success. We do not believe that attempts at management of Asian carps are futile, and "writing off" Michigan waters in which Asian carps have been detected is not a responsible approach.*

Strategic Actions

1. Follow AIS-HACCP (Gunderson and Kinnunen 2004) recommendations when conducting operations potentially influencing Michigan waters

Tasks

a. Cleaning / treatment of all gear used in invaded systems, or restrict gear from being used in multiple systems

Egg and juvenile transfer are potential pathways for introduction of Asian carps into new systems. This task recommends mandating cleaning and treatment procedures be employed by all DNRE units; including visual inspections of gear for juvenile fish, removal of entangled fish from equipment and proper disposal, and drying or treatment of nets and other gear used in invaded systems (see Fisheries Division Policy 02.02.020, "Interim Policy for Preventing the Spread of VHS by Fisheries Division's Survey Equipment"; also Gunderson and Kinnunen 2004,

Appendix 1). Conventional methods of treatment (hot-water pressure washing, chemical immersion) are probably sufficient to eliminate transfers of viable Asian carps among waters, but we should continue to evaluate new methods of treatment, relative to Asian carps life stages.

b. Develop a formal HACCP plan for Department operations

In addition to the immediate actions outlined above, Department staff should be charged with developing formal HACCP plans for DNRE operations, as well as model plans to be implemented by partners (individuals and agencies) in operations potentially influencing Michigan waters.

c. Regulate scientific collector's permit holders to ensure that transfer of Asian carps does not occur

Individuals and agencies applying to DNRE to sample fish in Michigan's waters should be required to follow the same gear use and disinfection standards as DNRE staff. These stipulations should be included in future permits issued by the Fisheries Division's ASRA Unit. While our group agreed that this was a good idea in principle, we recognize that enforcement of protocols on the multitude of SCP holders will be difficult.

d. The baitfish/aquaculture trade can reduce the risk of Asian carps transfer by adopting a certification approach similar to HACCP

To the extent possible, individuals and businesses engaged in the baitfish and aquaculture trades in Michigan should be required to follow the same gear use and disinfection standards as DNRE staff. These stipulations should be included in future permits issued by the Fisheries Division's ASRA Unit and Management Unit staffs, and in those granted by the MDA. Again, we recognize that enforcement of protocols will be difficult; this task will impose a significant additional workload on staff of the ASRA Unit, Fisheries Management Units, Law Enforcement Division, and the MDA.

To prevent the introduction of Asian carps, all aquaculture facilities and shipments should be certified as containing no AIS, including Asian carps; for example, by conducting eDNA testing or utilizing other approved inspection methods. Verification of new regulatory requirements such as certification (Asian carps-free and HAACP) and compliance with existing laws should include prior notification to the agencies with jurisdiction before movement, stocking, or importation of fish occurs in the state. The Michigan Bait Dealers Association (in compliance with DNRE and MDA) could conduct training and certification workshops for their memberships to ensure that proper testing and planning occurs.

2. Evaluate construction, maintenance, monitoring, operations, or removal of permanent and temporary barriers to dispersal of Asian carps

Tasks

a. Review and update (as needed) Fisheries Division's policies and procedures related to fish passage facilities

Fisheries Division policy 02.02.005, "Fish Passage", states:

"Fisheries Division will review the need for and make recommendations concerning fish passage for all new barrier construction, when significant dam repairs are proposed,

*when State money is used to repair or renovate a dam, and at dams that negatively impact aquatic species of concern...In determining whether fish passage is appropriate, consideration must be given to the fish species present above and below the barrier, site limitations such as access which may preclude cost-effective construction and maintenance, and design criteria that may limit effectiveness. **Negative impacts of fish passage, including passage of undesirable species, should be addressed before any fish passage project is implemented, especially if the dam is the first barrier from the Great Lakes [emphasis added].***"

Other applicable policies include FD 02.01.002 ("Dams and Barriers"), FD 02.01.003 ("Drain Construction and Maintenance"), and FD 02.02.006 ("Hydropower (FERC) Licensing Review"). We believe that Fisheries Division's policies adequately address the need for operational review of fish passage with respect to movement and range expansion of Asian carps. However, ongoing regular review of these policies will be an important component of adaptively managing Asian carps in Michigan's waters.

b. Review other Great Lakes-wide strategies and policies (e.g.; sea lamprey control, VHS management), with specific reference to fish passage facilities and possible applications to Asian carps management

(From GLFC web page) The Great Lakes Fishery Commission works with Fisheries and Oceans Canada, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers to undertake sea lamprey control. The control program uses several techniques to attack sea lampreys. This effort (known as "integrated sea lamprey management") includes: sea lamprey assessment, lampricide control, barriers, traps, and sterile male releases. As indicated in the Fisheries Division's policy "Dams and Barriers", placement of new sea lamprey barriers is guided by the GLFC Interim Policy and Guidelines for the Placement of Sea Lamprey Barriers in Great Lakes Tributaries". We will follow applicable parts of this policy when evaluating barriers for Asian carps management.

c. Review previously-developed geographic information system (GIS) layers, and develop new layers / databases (as needed)

Additional GIS layers specific to Michigan – illustrating river characteristics important to Asian carps spawning, locations of different types of fish passage and control facilities, and specific types of connectedness (e.g., open connection, managed connection, and intermittent connection) will be important tools in developing management plans for Asian carps should they reach Michigan's waters. These GIS layers and databases should be developed by the Fisheries Division's Institute for Fisheries Research (IFR) GIS working group, in consultation with managers of affected or potentially affected waters. Ideally, GIS development will be part of a larger risk assessment effort (e.g., Kolar and Lodge 2002, Aitkin et al. 2008, and Yi et al. 2010) aimed at improving our understanding of at-risk waters in Michigan.

d. Evaluate construction of current Michigan fish passage facilities and weirs to determine if modifications can be completed to contain Asian carps

Existing fish passage facilities and weirs provide us with one opportunity to prevent movement of Asian carps and to limit their introduction to new waters (or additional sections of existing waters) once they become established. Kolar et al. (2007) describe bighead carp as "robust swimmers", and current experience has shown that they are capable of efficient passage through

navigational locks. Ellis (1974) suggested that "...white amur [grass carp] can escape from impoundments having low dams and become established in adjacent water." While the only modification proven to prevent dispersal of Asian carps is a permanent physical barrier, Kolar et al. (2007) provide extensive discussion of physical and behavioral barriers that may prove useful in deterring or slowing dispersion (e.g., strobe lights, bubble curtains, acoustic deterrents, louver screen – see Chapter 11). The proposed Asian Carps Task Group (ACTG) should review the possible applicability of these tools at specific fish passage facilities (e.g., DNRE, USFWS, private hydropower facilities).

e. Evaluate operations of fish passage facilities and weirs in systems containing Asian carps to determine if operations should be modified to contain Asian carps

Our working group concluded that Fisheries Division should continue to recommend review of operational decisions for first barriers on Great Lakes tributaries on a case-by-case basis; **we did not develop blanket rules for closure of barriers**. This is consistent with Fisheries Division's policy on fish passage, as well as current practice in relation to VHS management. These decisions should be made through consultation among managers and upstream resource users and discussion of the programmatic, ecological, and social importance of the upstream waters, as well as the costs related to closure of fish passage. For example, on the St. Joseph River, agency staff in Indiana should be engaged in discussions about management of fish passage on that system – potential costs of invasion by Asian carps versus effects of closure on the Indiana economy.

f. Consider Asian carps range expansion and ecological effects when reviewing water control structure projects and permits

While Fisheries Division has specific abilities to control fish passage at facilities we operate or own outright, we also have some ability to influence fish passage at non-DNRE facilities; for example, at hydropower facilities licensed by the Federal Energy Regulatory Commission. As stated in FD 02.01.002 ("Dams and Barriers"), "The Michigan Department of Environmental Quality Land and Water Management Division [now DNRE] has regulatory authority over all new dams, certain existing dam structures which may be periodically repaired, modified, or removed when practical, and water management practices at dams on public waters. Fisheries Division staff will review these proposed activities and provide comments and concerns to DEQ [now DNRE] in a timely manner."

Fisheries Division's staff charged with reviewing dam and barrier construction, modification, and operations should take the potential for range expansion by Asian carps into account as a priority factor when conducting reviews and making recommendations. The benefits of allowing new fish passage should be well-supported in cases where Fisheries Division's staff recommendations could open new areas to Asian carps. An example of such a case might be restoring areas for lake sturgeon spawning. In addition to our own review activities, Fisheries Division's staff should continue to coordinate closely with USFWS, GLFC, USACOE, and others having responsibilities to review fish passage projects for tributaries to the Great Lakes.

3. Encourage commercial and recreational harvest

Tasks

a. Examine commercial harvest regulations and consider changes to help eradicate Asian carps

Current commercial fishing operations in Michigan's waters are either State-licensed fisheries or tribal fisheries. The State-licensed fishery (cumulative) is operated under a limited entry policy, with no new licenses issued and only those persons licensed in the preceding year eligible to be issued a current year license (see Fisheries Division's policy 01.01.006, "Issuing, Rescinding, and Amending Commercial Fishing Licenses"). Some current State-licensed commercial fishers have expressed interest in beginning operations to target Asian carps; tribal fishers may also be interested in this opportunity.

If current State-licensed commercial fishers are interested in pursuing fishing opportunities in areas where Asian carps have been detected, and if there is no additional cost to Fisheries Division (i.e., beyond existing licensing oversight and monitoring by the Fisheries Division's staff in the ASRA), we believe that these operations should be encouraged. Changing permitted fishing locations and allowable gear types to encourage removal of Asian carps could likely be handled through a license amendment process (see FD 01.01.006); we believe that this should be the first avenue explored in considering changes to commercial harvest regulations. Adding additional State-licensed commercial fishers would require a change to existing policy in Fisheries Division, and may also require statutory changes.

Under any of the above scenarios, use of entrapment gear should be encouraged to minimize effects on important populations of fish. Catch should be sorted and non-Asian carp species released. Fisheries Division would need to adopt a protocol for evaluating harvest (i.e., extraction of Asian carps) and bycatch mortality; this may also require additional gear evaluation by commercial fishers and Fisheries Division's biologists. Requests by State-licensed commercial fishers targeting Asian carps to retain non-Asian carp species will necessitate expansion of Fisheries Division's monitoring and should be considered under Task 3.b.

b. Provide incentives for commercial fishers to increase harvest

An unwillingness on the part of State-licensed commercial fishers to expand operations to target Asian carps probably means that there is little or no commercial market for these species. Kolar et al. (2007) describe commercial fisheries for Asian carps on the Mississippi, Missouri, and Illinois rivers, but also indicate that a previous market for live fish has diminished significantly due to increased regulation of the possession, transport, and sale of live fish. If a commercial outlet for Asian carps is not available and Fisheries Divisions wants to adopt a commercial harvest strategy as part of our overall management plan for Asian carps, then some type of incentive will need to be provided to State-licensed commercial fishers. Incentives could include allowing State-licensed commercial fishers to retain non-Asian carp species that are currently allowed for commercial take (e.g., lake whitefish and suckers), or providing payments to State-licensed commercial fishers for removal of a specified biomass of Asian carps.

The first incentive strategy (allowing retention of commercially marketable species in addition to Asian carps) would require significant expansion of Fisheries Division's monitoring and data analysis activities. A quota management system – similar to the Lake Erie walleye or 2000 Consent Decree lake whitefish and lake trout management plans – would need to be initiated. Data collection would need to be expanded to document population parameters for the species and areas of interest, and biologists would need to be tasked with developing safe harvest limits for these species and areas. A conservative estimate of the annual costs of implementing such a

system is \$100,000 per species for each area (based on existing Federal Aid study budgets and staff salaries).

The second incentive strategy (providing direct payments to fishers) is analogous to the harvest strategy for salmonids at weirs operated by Fisheries Division. DNRE currently contracts with a private fish processor / wholesaler to harvest and market salmon and salmon eggs from State-owned weirs that are excess to the State's hatchery production needs. While a contract would need to be developed for the specific circumstances (timing of operations and target biomass to be removed) related to removal of Asian carps, the current DNRE contract for salmon removal (\$220,000 annually, three year contract period) is a useful reference for consideration.

While these two incentive strategies should be considered as possible alternatives in an Asian carps management strategy for Michigan, we believe that they should be reserved as lower priority, more expensive actions. Actions necessary to implement these incentives would require increased funding for additional wholesale reporting and monitoring by DNRE's Law Enforcement Division.

c. Examine recreational harvest regulations and consider changes to help eradicate Asian carps

Published recreational regulations, DNRE's Fisheries Orders, and State statute prohibit possession or transport of live bighead carp, black carp, largescale silver carp, silver carp, or grass carp (see Section 3, "Policy Background"). These provisions are consistent with a goal of eradicating, containing, and managing Asian carps – as is a provision for retention of dead specimens of these species by recreational anglers. Future published issues of the "Michigan Fishing Guide" should clarify the legality of harvesting species of Asian carps (including modification to net use restrictions – Table 5 of 2010 volume – and spearing / bowfishing restrictions – Table 6), recreational anglers should be informed concerning the location(s) of established populations of Asian carps, and recreational harvest should be encouraged (see Goal II). Additional language should be included under the current guidelines for "prevent[ing] the spread of fish diseases and other aquatic nuisance species" (page 39 of 2010 volume), specific to encouraging harvest and preventing range expansion of Asian carps.

While the likely effect of recreational harvest on population expansion by Asian carps is negligible, encouraging harvest is entirely consistent with a goal of eradicating, containing, and managing Asian carps. We believe that recreational harvest should be encouraged.

4. Physically remove incidental catches of Asian carps during fisheries surveys, when practical

Task

a. Field staff should manually remove incidentally caught Asian carps during management or research actions and follow protocols for appropriate disposal

Low densities of Asian carps may occur during initial colonization or expansion of their distribution in Michigan's waters. Asian carps may be captured as non-target species during fisheries surveys. Natural resource agencies and universities conducting surveys should physically remove Asian carps when practical. In any situation it is highly undesirable to release live Asian carps back to the wild following capture, and incidental removal may help to contain

localized populations. Should catch rates of Asian carps become high, an indication that populations are abundant and thriving, this approach may not be practical and larger-scale removal operations may be necessary. Recommended actions under this task include:

- follow Fisheries Division's Prescription process for large-scale removal operations and implement only if the situation can be altered, or if there is a documented negative effect by Asian carps on native populations of fish or species of prey (e.g., zooplankton);
- incorporate within the scientific collector's permit program a procedure for permit holders to remove Asian carps during surveys, a standardized process for documenting their distribution, and an appropriate disposal protocol; and
- test incidental catches of Asian carps for ploidy. Adult grass carp have been captured repeatedly in the St. Joseph River, indicating that they are able to survive in this system. Multiple adult grass carp have also been captured in Muskegon Lake. Reproduction has not been confirmed in either of these systems, and it is unknown whether any of the individual grass carp captured from Michigan waters were diploid (i.e, reproductively viable) or triploid. Ploidy determinations from captured Asian carps would assist in determining the source (naturally produced or stocked) of captured Asian carps.

5. Implement chemical piscicide eradication plans, if Asian carps create negative ecological, economic, or social effects in Michigan

In some cases, likely after the detection and assessment of potential ecological effects of Asian carps, it may be decided to attempt to eradicate fish before long-term effects occur. Use of chemical toxicants (piscicides) to affect significant mortality on Asian carps is the only realistic method available for removal. This strategy will require substantial effort by natural resource agency staff and significant financial commitment. Therefore, before this strategy is implemented, scientifically sound and cost-effective approaches must be evaluated to determine if they will reduce populations of Asian carps while having limited negative effects on species important to the State of Michigan. We recommend the following steps and considerations for implementation of chemical removal operations in Michigan's waters.

Tasks

a. Determine regulation needs for the use of piscicides to control Asian carps

A permit is required for applications of piscicides to waters of the State under sections 3103 and 3106 of 1994 PA 451, where Administrative Rule 97 (certification) applies to the application of materials for water resource management projects pursuant to State statutory provisions and not subject to other water quality standards. A certified applicators license is required by the MDA to apply pesticides.

b. Identify conditions where rotenone or antimycin *a* could be used to significantly reduce populations of Asian carps, should they become self-sustaining in Michigan

Originally, piscicides were used to control undesirable populations of fish so that sport fish could be stocked and managed for recreational purposes without predation, competition, or interference by undesirable fish (Finlayson et al. 2000). Rotenone has been widely used to quantify fish communities in many of Michigan's river systems (Nelson and Smith 1980, Towns 1984, Towns

1987, Dexter 1991). Chapman et al. (2003) examined the sensitivity of bighead and silver carps to rotenone and antimycin *a*. This study found that bighead and silver carps were sensitive to rotenone at low concentrations (15-250 µg/l), but were insensitive to antimycin *a*, even at relatively higher concentrations of 20 µg/l. Chapman et al. (2003), along with other studies (Gilderhus 1972, Marking and Bills 1976, and Finlayson et al. 2002), indicates that the contact period necessary to affect removal of bighead and silver carps with antimycin *a* would be inappropriately long compared to the time of exposure to rotenone, although antimycin *a* may have longer residual effects that could lead to delayed mortality of exposed fish compared to rotenone. It is our recommendation that rotenone be used to remove Asian carps in field applications to ensure a complete kill within a reasonable contact period.

From 1987-1992, Michigan Department of Natural Resources' staff conducted rotenone sampling at 42 sites on 13 river systems varying in size (mid-sized warmwater to small-sized coolwater), mean channel width (19 to 115 ft.), and flow (10 to 2,000 ft³/s) characteristics. Standardized procedures for this process involved rotenone application at 3 ppm (formulation rate) at the upstream end of the station for an exposure time of 35 min and, as rotenone (marked with a dye) reached the lower end of a station, a neutralizing agent (potassium permanganate) was applied at 5 ppm (formulation rate) for 45 min (Seelbach et al. 2000). Concentrations of rotenone used by Fisheries Division's staff are considerably higher than concentration rates used by Chapman et al. (2003) to effectively kill bighead and silver carps. It is recommended that only concentration rates up to 0.250 mg/l rotenone be used, as recommended by product labels and in Chapman et al. (2003). Other concentrations could be used if justified by additional studies. Engstrom-Heg (1972) reported that at formula concentration rates above 3.4 ppm, rotenone goes into a colloidal state, suggesting that it is wasteful to apply rotenone at any higher concentrations.

Piscicide applications may be more efficient for removal of different size groups of Asian carps and for applications in vast habitat types. Conditions where application of piscicides may be most efficient include anthropogenic areas where populations of Asian carps are confined or concentrated. Such areas may include backwater areas of rivers, small embayments, marina basins, dredged channels or warmwater discharge outfalls. These areas typically do not support large numbers of desirable sport fish and could result in the highest beneficial use of piscicides. This method may also be effective during periods of the year when Asian carps are concentrated during spawning events or confined individuals occur in an area that would be susceptible to removal through toxicants.

c. Determine costs of piscicide applications to eradicate Asian carps; evaluate availability of piscicide

The following example scenarios (see Table 3 for details) could be implemented, depending on progression of Asian carps in Michigan's waters:

Scenario I – Asian carp spawning populations were assessed in the St. Joseph River and determined to be causing some ecological effect, and eradication using rotenone was approved from Berrien Springs Dam to the rivermouth at Lake Michigan.

Scenario II – A population of Asian carp becomes established in Mona Lake, Muskegon County, and eradication using rotenone was approved.

d. Write Fisheries Management Plan and Public Involvement Plan as required within Fisheries Division's Policy 02.03.001 ("Policy for use of Piscicides and other compounds by Fisheries Division in ponds, lakes, and streams")

e. Implement specific chemical removal plans as appropriate

6. Utilize new technologies, as available and appropriate, to contain or manage Asian carps

New management tools may become available; these may be necessary to control or eradicate Asian carps if they become established in Michigan's waters. Chemical control measures have been applied to control sea lamprey in the Great Lakes, but such measures may also affect non-target native species. The use of species-specific repellants and lures, based on natural pheromones may be more effective. Numerous species of fish, including cyprinids such as bighead and silver carps, have an alarm pheromone that is produced by cells in the outermost layer of fish skin (Pfeiffer 1977). This substance is released into the water upon damage to the skin overlying the scales as would occur during attack by a predator. Because of the effectiveness of alarm substances as a repellant, use of alarm substance extracts may provide a chemical barrier to prevent movement of Asian carps into Michigan's tributaries during periods of migration or dispersal. Reproductive pheromones are signals that mediate reproductive interactions between similar species of fish. Asian carps probably also release these pheromones as described in other common carp and goldfish. These pheromones often result in gonadal development or specific behaviors such as attraction, nest preparation or nest defense, and spawning behaviors (Wilson and Bossert 1963). Studies need to be conducted to determine if Asian carps respond to these technique, and to characterize the response and describe when during development the response occurs, before these techniques can be implemented. We envision the Asian Carps Task Group (ACTG) as taking the lead on the review and recommendation of new technologies for the prevention and control of Asian carps.

Tasks

a. Reduce populations of Asian carps through supplementing or introducing biological controls such as native predator enhancement

Biomasses of forage fish often become high in the absence of large predators to control their prey. The use of biological controls has historically not been recommended to manage populations of invasive species because unintended effects to native species already stressed are not typically known until after implementation. Predation by native predators is likely to affect only early life stages of Asian carps. Asian carps grow quickly; predation is not likely to exert population level changes in many waters of concern. Despite this limitation, reductions in Asian carps recruitment by introduction or enhancement of native predators (e.g., Great Lakes-strain muskellunge) may have cumulative effects when used with other strategies, while at the same time creating angler opportunity. Introduction of native predators for control of Asian carps will be done after full evaluation of the potential costs and benefits, and of the likelihood of success (see Beamesderfer 2000 for a suggested evaluation framework).

b. Determine if Asian carps respond to new deterrent technologies. (e.g., chlorine, Ethylene glycol, bubble screens, acoustic deterrent devices, louver screens)

While the only modification proven to prevent dispersal of Asian carps is a permanent physical barrier, Kolar et al. (2007) provide extensive discussion of physical and behavioral barriers that

may prove useful in deterring or slowing dispersion. Fisheries Division's staff should review the possible applicability of these tools at specific fish passage systems, weirs, or at the mouth of important tributary streams.

Acoustic deterrent systems have been used to reduce impingement of alewives at power plant intake structures (Ross et al. 1996). However, the technology did not completely prevent impingement of all fish, thus the potential to affect the behavior of Asian carps is unknown at this time. Use of acoustic deterrent systems may be beneficial as a tool by inhibiting passage at weirs or fish ladders while still allowing for passage of other fish. Bubble screens, acoustic systems, or louver screens may also be beneficial tools by disrupting spawning aggregations and reducing recruitment in Great Lakes tributaries.

These action items, while no less critical than other actions, will take more money, time, and investigation to implement. Should Asian carps become established, these technologies may be important to the conservation of the Great Lakes ecosystem. Therefore investigations on the utility of deterrent technologies should begin prior to invasion of Asian carps into Michigan's waters, in coordination with DNRE partners at Great Lakes universities.

c. Determine if methods to disrupt spawning behavior and decrease egg viability (e.g., pheromones, genetic manipulations) are applicable within Michigan

Genetic modifications that result in transgenic fish expressing selective traits to control fish populations or the release of genetically altered fish are not recommended at this time. The introduction and possession of transgenic species is prohibited within the State. Furthermore this strategy would either require the presence of a large number of transgenic individuals or many generations of offspring to be effective.

Pheromones are not recommended until research has determined this technique to be effective and until populations become established to justify this strategy. Preliminary evidence has suggested some success with effective control of sea lampreys in the Great Lakes through the release of pheromones to enhance their capture (e.g., Li et al. 2002; Weiming Li, Michigan State University, personal communication). If pheromones provide a technique to aggregate large numbers of fish to effectively remove and control populations, then pheromones from Asian carps may eventually become a useful management tool.

d. Evaluate applicability of new chemicals to control populations of Asian carps when they become approved for use

Currently, only rotenone, antimycin *a*, and the lampricides Lamprecid and Bayluscide are registered by the United States Environmental Protection Agency (USEPA) for use in the United States. Of particular importance would be the development of a fish toxicant selective for Asian carps for removal from natural bodies of water. Since bighead and silver carps are pelagic, application to the epilimnion of the water column may not affect native benthic fish.

5) IMPLEMENTATION

General overview of implementation

The implementation table (Table 4, below) serves to summarize more detailed information provided within Section 4 (Management Actions). The implementation table outlines information for each proposed strategic action, including: lead and cooperating agencies, projected costs and effort, current status of proposed action, implementation approach, and general timeline for tasks.

6) PROGRAM MONITORING AND EVALUATION

Glassner-Shwayder (1996) notes that a state AIS management plan should include a monitoring/evaluation section that details means to monitor progress, evaluates implementation problems and needs, and outlines provisions for making necessary "midcourse" corrections. Our proposed program monitoring and evaluation plan follows most of Glassner-Shwayder's recommendations (with some minor modifications / additions).

- We recommend **establishment of an oversight committee**, described in more detail under Goal II (Communication, see Asian Carps Task Group). The purposes of the group will be overseeing prevention, communication, detection, assessment, and management efforts; disseminating the results of these efforts; and identifying plan changes necessary to meet outlined goals. As stated in Glassner-Shwayder (1996), "The evaluation process should be inclusive, involving those with implementation responsibility, resource user groups and others affected by plan implementation." We recommend the following agency members as initial participants on this oversight committee: Fisheries Division (ASRA, Management Units, and Great Lakes research representatives), Water Resource Division, OGL, Law Enforcement Division, Media and Communications Office, and MDA. Ultimately, these efforts will likely be integrated with those of the AIS Core Program, coordinated by the Water Resource Division. Resource user groups and others may be added after initial discussion among agency members.
- The five plan goals, as presented earlier, will provide the focal point for program evaluation. As indicated in Glassner-Shwayder (1996), **measurable objectives** should be assigned to each of these goals, to provide meaningful evaluation of progress and success. Suggested measurable objectives associated with each of our proposed goals are included in Table 5.
- **Identification of funding needed to successfully accomplish goals and associated tasks** is also a critical part of this plan. Estimated funding needed to address goals and strategies is described in Section 4; more general estimated needs are presented in the associated implementation table (Table 4).
- The DNRE is committed to adopting holistic resource management processes, based in large part on the principles of ecosystem management. One of these principles is that of adaptability / accountability; (from the DNRE's "Ecosystem-Based Management" web page) "Ecosystem management acknowledges that current knowledge and paradigms of ecosystem functions are provisional, incomplete, and subject to change. Management approaches must be viewed as hypotheses to be tested by research and monitoring programs." With this principle in mind, we believe that an **adaptive management strategy** will be an important component of program evaluation (DNRE 2010). Adaptive management necessitates a concerted effort to evaluate management actions, so that relative success can be documented. An adaptive management strategy also requires a willingness to modify assumptions, goals, and actions based on new information gained through monitoring efforts, with subsequent actions adapted for greater effectiveness.

The oversight committee (see above, Asian Carps Task Group) will be responsible for adopting an ecosystem-based, adaptive management approach to the problems of prevention and management for Asian carps. We believe that the goals and strategies outlined in our plan describe such an approach; relevant important components of this

approach include clearly stated (quantifiable) goals and objectives, incorporation of research and monitoring as important components of management actions, identification of resources needed for program implementation, and regular review and application of new information.

- The oversight committee (see above) will be responsible for **preparation and dissemination of an annual report** highlighting implementation progress, including an evaluation of the efficacy of the plan's strategies and tasks. At a minimum, this report will be delivered to DNRE division management teams, to appropriate MDA management teams, and to the Council of Lake Committees (to keep other Great Lakes states informed as to activities undertaken and successes experienced in Michigan). Additional distribution of this report will occur at the discretion of the oversight committee.

7) TABLES

Table 1. Survey scenarios to evaluate localized abundance of Asian carps; specific design based on water body characteristics. Approximate cost includes salaries and fringe benefits (combined, 80% of total survey cost), using the following hourly rates - \$38.18/Tech, \$49.27/Bio, \$57.86/Mgr. Additional associated survey costs (equipment / supplies, travel, and vehicle services) were included as a fixed percentage (20%) of the total.

Assessment scenario	Assessment method	Annual cost	New or existing program	FTEs needed	Duration
<i>Scenario I – Assessment of Asian carps in open waters of the Great Lakes (e.g.; expansion into southeastern Lake Michigan or Lake Erie)</i>	Hydroacoustic survey	\$48,270	New	5	4 weeks
	Gill / Trammel net assessment	\$76,832	New	4	8 weeks
<i>Scenario II – Assessment of Asian carps in an important Great Lakes tributary (e.g.; St. Joseph River, Grand River, Muskegon River)</i>	Electrofishing, plus early life history survey (egg/larval sampling)	\$50,251	New	6	4 weeks
	Gill / Trammel net assessment	\$50,251	New	6	4 weeks
<i>Scenario III – Assessment of Asian carps in a drowned rivermouth lake (e.g.; Muskegon Lake, Lake Macatawa)</i>	Hydroacoustic survey, plus electrofishing	\$50,251	New	6	4 weeks
	Commercial contract	\$40,000	New	Contract	4 weeks

Table 1. Continued.

Assessment scenario	Assessment method	Annual cost	New or existing program	FTEs needed	Duration
<i>Scenario IV – Assessment of Asian carps in an inland lake or impoundment</i>	Preferred Assessment Method				
	Population estimate ("Large Lake" methodology)	\$52,470	New	12	3 weeks
	Alternate Assessment Method				
	Status and Trends methodology	\$6,281	New	3	1 week

Table 2. Survey scenarios to evaluate likely effects of Asian carps on fish populations and parameters of concern identified in Goal IV, Strategy 1.a. Approximate cost based on Federal Aid in Sport Fish Restoration assessment/survey projects (or other ongoing representative projects) conducted in similar waters. For Scenario I, costs are a range of actual Federal Aid grant awards for the projects listed. Estimated costs for Scenarios II-IV were calculated as described for Table 1.

Assessment scenario	Preferred assessment method(s)	Federal Aid (or other) project reference	Approximate 5-y cost (or range)	New or existing program	FTEs needed	Duration
<i>Scenario I – Assessment of a yellow perch population in open waters of the Great Lakes (e.g.; expansion into southeastern Lake Michigan or Lake Erie)</i>	Adult and recruit surveys, creel surveys	230466, 230484, 230488, 230747	\$400,000 - \$800,000	Existing (but may need to expand coverage)	3 (plus additional seasonal positions)	5 years (4 weeks per year)
<i>Scenario II – Assessment of a walleye population in a Great Lakes tributary (e.g.; St. Joseph River, Grand River, Muskegon River)</i>	Adult population estimate, natural reproduction estimate	St. Joseph River walleye assessment	\$250,000	Existing on some systems	6	5 years (4 weeks per year)
<i>Scenario III – Assessment of walleye and yellow perch populations in a drowned rivermouth lake (e.g.; Muskegon Lake, Lake Macatawa)</i>	Adult population estimates / surveys, creel surveys, fish community evaluation	230725 ("Large Lake" project)	\$350,000	New	12	5 years (3 weeks per year)
<i>Scenario IV – Assessment of fish assemblages in an inland lake or impoundment</i>	Standard "Status and Trends" survey	230712	\$35,000	New	3	5 years (1 week per year)

Table 3. Example scenarios involving piscicide application for eradication of Asian carps. Estimated costs associated with this action include rotenone (\$34.95/gal), potassium permanganate (\$2.35/lb), and salaries and wages for 30 staff (\$38.18/Tech, \$49.27/Bio, \$57.86/Mgr. Additional associated costs (equipment / supplies, travel, and vehicle services) were included as a fixed percentage (20%) of the total (minus chemicals).

Eradication scenario	System	Conditions	Duration (days)	Chemical needs	FTEs needed	Cost (Salary + Fringe)	Cost (equip., travel, vehicles)	Cost (chemicals)	Total cost
<i>Scenario I – Asian carp spawning populations were assessed in the St. Joseph River and determined to be causing some ecological effect, and eradication using rotenone was approved from Berrien Springs Dam to the rivermouth at Lake Michigan.</i>	St. Joseph River (5 sites - Berrien Springs to Lake Michigan)	Large, warmwater river. Average 40-year June discharge = 3,540 cfs. Calculated reach turnover of 24 hours, based on June flow data.	5	2,371 gal rotenone; 1,990 lbs KMnO2	30 (per site)	\$322,641	\$80,660	\$87,556	\$490,857
<i>Scenario II – A population of Asian carp becomes established in Mona Lake, Muskegon County, and eradication using rotenone was approved.</i>	Mona Lake (whole-lake treatment)	Lake volume calculated at 9,870 acre-ft.	2	9,652 gal rotenone; 19,302 lbs KMnO2	30	\$27,825	\$6,956	\$382,697	\$417,478

Table 4. Implementation table, showing (for each strategic action); lead and cooperating agencies, projected costs and effort, current status of proposed actions, and implementation approach. Priority order of proposed actions is generally from the top of the table to the bottom (i.e.; Prevention highest priority, Communication second highest priority...). Specific discussion of actions that should be implemented as soon as possible is included in the concluding paragraphs of the Executive Summary.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
I. Prevention - Prevent the accidental or deliberate introduction of bighead, black, grass, and silver carps in Michigan.	1) Prevent transport and release or improper disposal of Asian carps that may be intermixed with baitfish.	DNRE Fisheries Division's ASRA Unit.	DNRE Law Enforcement Division (LED), Michigan Department of Agriculture (MDA), private sector (retailers, baitfish industry, aquaculture, anglers).	Extra staff required for oversight and inspections (Fisheries Division, LED). Funding opportunities should be explored with Office of Great Lakes (OGL).	Ongoing, but often informal and inconsistent.	A) Improve effectiveness of existing regulations, laws, and authorities. B) Increase inspection of baitfish distributors and hauling equipment. C) Improve communication with stakeholders on both existing regulations and the negative effects of Asian carps.
	2) Control ongoing and permitted fish stocking efforts to prevent inadvertent introduction of Asian carps.	DNRE Fisheries Division's ASRA Unit; DNRE Fisheries Division's Management Units.	DNRE LED and OGL, MDA, private sector (retailers, aquaculture, anglers, permit holders).	Extra staff required for oversight and inspections (Fisheries Division, LED). Funding opportunities should be explored with OGL.	Ongoing, but often informal and inconsistent.	A) Improve effectiveness of existing regulations, laws, and authorities. B) Increase inspection of fish distributors and hauling equipment. C) Improve communication with stakeholders and regulatory partners.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
	3) Prohibit import, possession, sale, purchase, and intentional introduction of live Asian carps.	DNRE Fisheries Division’s ASRA Unit.	DNRE LED and OGL, MDA, private sector (retailers, aquaculture, anglers).	Extra staff required for oversight and inspections (DNRE Fisheries Division, LED). Funding opportunities should be explored with OGL.	Ongoing, but often informal and inconsistent.	A) Improve effectiveness of existing regulations, laws, and authorities. B) Increase inspection of fish distributors and hauling equipment. C) Improve communication with stakeholders and regulatory partners.
	4) Work with other agencies and partners to prevent introduction or range expansion of Asian carps in situations where we have common interests or existing cooperative agreements for management.	DNRE Fisheries Division’s Basin Coordinators.	Canada, Federal agencies, state agencies, tribal agencies.	Commitment of existing staff time.	Ongoing, but often informal and inconsistent.	Improve communication, Asian Carp Regional Coordinating Committee participation, unify support for actions that prevent spread of Asian carps (e.g., ecological separation), review status of Asian carps on regular bases, review issue of stocking of grass carp in border states.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
II. Communication - Effectively share information to improve management and control of bighead, black, grass, and silver carps in Michigan.	1) Develop educational materials related to the identification of Asian carps.	DNRE Media and Communications.	DNRE Fisheries Division and OGL, Michigan Sea Grant, public partners.	Staff time for development and web posting. Production costs for Fishing Guide, posters, and signage.	New- Material available from other agencies related to adult identification. Material for identifying juvenile carp is needed.	Web based information, Fishing Guide, hard copies, boat access signage, other media.
	2) Develop educational materials describing the potential negative effects of Asian carps and methods to prevent their introduction.	DNRE Media and Communications.	DNRE Fisheries Division and OGL, Michigan Sea Grant, public partners.	Staff time for development and web posting. Production costs for Fishing Guide, posters, and signage.	Limited information already on DNRE web page. Existing materials available from other agencies.	Web based information, Fishing Guide, hard copies, boat access signage, other media.
	3) Develop educational materials describing regulations pertinent to preventing the introduction of Asian carps.	DNRE Media and Communications.	DNRE Fisheries Division and OGL, Michigan Sea Grant, public partners.	Staff time for development and web posting. Production costs for Fishing Guide, posters, and signage.	Limited information in Fishing Guide related to Aquatic Invasive Plants and Animals.	Web based information, Fishing Guide, hard copies, boat access signage, other media.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
	4) Develop educational materials describing human health and safety issues related to establishment of Asian carps.	DNRE Media and Communications.	DNRE Fisheries Division and OGL, Michigan Sea Grant, public partners, Michigan Department of Community Health (MDCH).	Staff time for development and web posting. Production costs for Fishing Guide, posters, and signage.	New- Existing materials available from other agencies related to physical risks and contaminant burden.	Web based information, Fishing Guide, hard copies, boat access signage, other media.
	5) Effectively communicate with the public regarding Asian carp developments and our response strategies.	DNRE Media and Communications.	DNRE Fisheries Division's Management Units and OGL, Michigan Sea Grant, public partners.	Staff time for development and distribution of information. Fisheries Division's staff time for response to public reports.	New- Existing materials available from other agencies related to public communication.	Keep public informed of changing situation, current status through press releases, social media, and web-based information. Need to explore best methods for public communication back to DNRE.
	6) Develop DNRE and MDA Asian Carps Task Group and communication system.	DNRE Fisheries Division's Management Team.	DNRE Fisheries Division's ASRA, Management Units, and Great Lakes research, WRD, OGL, LED, Media and Communications, WLD, and MDA.	Commitment of existing staff time.	New.	Insure coordinated response and review of Asian carp issues, including review and recommendation of new technologies. Recommend immediate formation, to discuss regulatory framework, funding. Future expansion of group and meetings as threat increases.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
III. Detection - Detect the presence of bighead, black, grass, and silver carps in Michigan.	1) Implement an eDNA surveillance strategy for Michigan's waters, based on Asian carps distribution and likely risk to Michigan waters.	DNRE Fisheries Division.	University of Notre Dame Center for Aquatic Conservation (CAC).	Cost of sample collection, processing and analysis.	New.	Implement a tiered / prioritized surveillance approach in Michigan's waters, based on progression of Asian carp expansion in the GL Basin and on likely risk to specific Michigan waters. Begin coordination with ongoing GL efforts as soon as possible. Additional surveillance dependent on sample cost, funding, threat.
	2) Use an informed public (including commercial fishers, recreational fishers, and fish distributors) to enhance monitoring for introductions of Asian carps.	DNRE M&C, DNRE Fisheries Division's Management Units, DNRE OGL.	Michigan Sea Grant, public partners.	Minimal - communication / education costs (see above).	New.	Tied to communication efforts. Web communication back to DNRE, with distribution to Fisheries Division's Management Units for action. Identify agency lead person for tracking (discussion of OGL role; may also be left for decision by ACTG). See also Angler's Monitoring Network.
	3) Develop monitoring network through an expanded scientific collector's permit (SCP) system.	DNRE Fisheries Division's ASRA Unit.	DNRE OGL.	Minimal - communication / education costs. Additional staff time.	Expansion of existing system.	Modify to facilitate reporting and "handling" of Asian carps.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
	4) Utilize existing inland and Great Lakes fishery survey efforts to detect the presence of Asian carps.	DNRE Fisheries Division's Management Units and Research.	Other agencies if not included in SCP (need to investigate rules on this).	No additional cost to existing surveys. Increased cost would be associated with expanded assessment efforts (see Goal IV).	Ongoing.	Training of agency staff in Asian carp identification. Increased vigilance for the presence of Asian carps.
	5) Monitor fish passage systems and weirs to assess the movement and distribution of Asian carps in Michigan rivers.	DNRE Fisheries Division's Management Units and Habitat Management Unit (HMU).	Hydropower utility companies, USFWS.	Fill at least one position to analyze video records.	Ongoing.	Monitor fish ladders with existing video recording equipment; other systems through ongoing assessment methods. Look for opportunities to implement additional enumeration technologies. Some monitoring ongoing; expand implementation with additional funding. Surveillance levels and locations tied to threat.
IV. Assessment - Gather population level data on Asian carps at areas where they have been detected in Michigan's waters; measure response of Michigan's fish populations to introduction of Asian carps.	1) Implement expanded fisheries surveys in waters where Asian carps have been detected, with survey designs linked to likely management actions in waters of concern.	DNRE Fisheries Division's Management Units and Research.	Other agencies (USFS, USFWS, other states, tribes, universities, USGS).	Cost proportional to waters of infestation. May need additional staff.	New.	A) Review Asian carp detection event, evaluate assessment costs. B) Design and implement Asian carp survey. C) Design and implement fish population survey. D) Analysis, evaluation, technology transfer. Implementation dependent on presence of Asian carps. A detection event may trigger assessment activities; specifics dependent on system, background data, management problem.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
<u>V. Eradication / Containment / Management</u> - Eradicate, contain, or manage populations of Asian carps if they become established.	1) Follow AIS-HACCP (Gunderson and Kinnunen 2004) recommendations when conducting operations potentially influencing Michigan waters.	DNRE Fisheries Division.	Scientific collector's permit (SCP) holders.	Additional time required to follow procedures, relative to not implementing. Multiple sets of equipment.	Ongoing.	A) Disinfect / restrict gear. B) Develop formal HACCP plan. C) Regulate SCP holders. D) Encourage / require adoption by industry.
	2) Evaluate construction, maintenance, monitoring, operations, or removal of permanent and temporary barriers to Asian carp dispersal.	DNRE Fisheries Division's Management Units and Habitat Management Unit (HMU).	DNRE permitting staff (i.e., WRD), dam / water control structure operators (e.g., drain commissioners).	No additional cost associated with reviews. Substantial cost for construction. Non-monetary costs (e.g., blocked passage of desirable species).	Ongoing, but with increased scrutiny relative to Asian carp.	A) Review and update FD policies. B) Review other Great Lakes policies. C) GIS development. D) Evaluate construction. E) Evaluate operations. F) Consider Asian carp in reviews. Further implementation dependent on presence of Asian carps.
	3) Encourage commercial and recreational harvest.	DNRE Fisheries Division's ASRA Unit and Tribal Coordination Unit (TCU).	DNRE Fisheries Division's Management Units, DNRE M&C, commercial fishers, recreational fishers, DNRE LED.	Minimum cost - some staff time related to regulation review, program oversight. Maximum costs - incentives, gear purchase, other subsidies.	New.	A) Review and evaluate commercial regulations. B) Provide incentives to commercial fishers. C) Review and evaluate recreational regulations. Regulation review, incidental harvest monitoring recommended within the next year. Further implementation dependent on Asian carp status.

Table 4. Continued.

Goal	Strategy	Lead	Cooperators	Cost / Budget	Status	Implementation / Action
	4) Physically remove incidental catches of Asian carps during fisheries surveys, when practical.	DNRE Fisheries Division's Management Units and Research.	DNRE M&C, scientific collector's permit (SCP) holders, partners in other agencies.	Cost proportional to extent of removal.	New.	A) Incidental removal as possible in routine surveys. B) Follow existing prescription process for large removal efforts (includes peer review). C) Incorporate within scientific collector's permit process. Incidental could begin immediately. Further implementation dependent on Asian carp status.
	5) Implement chemical piscicide eradication plans should Asian carps create ecological, economic, or social effects in Michigan.	DNRE Fisheries Division's Management Units.	DNRE Fisheries Division, DNRE M&C, chemical manufacturers, USEPA, DNRE permitting staff (i.e., WRD).	Cost proportional to extent of removal.	New.	A) Determine piscicide regulation needs. B) Identify appropriate conditions. C) Determine costs. D) Write management and public involvement plans. E) Implement plan. Implementation dependent on Asian carp status.
	6) Utilize new technologies, as available and appropriate, to contain or manage Asian carps.	DNRE Fisheries Division's Research, Management Units, and HMU.	Asian Carps Task Group, Great Lakes university researchers.	Staff time.	New.	A) Biological controls. B) Deterrent technologies. C) Disrupt spawning, decrease egg viability. D) New piscicides.

Table 5. Suggested measureable outcomes for each plan goal (see Table 4 and text for additional description).

Goal	Outcome
<p>Goal I: Prevent the accidental or deliberate introduction of bighead, black, grass, and silver carps in Michigan</p>	<ul style="list-style-type: none"> a) No Asian carps inadvertently introduced through bait fish movement b) No Asian carps inadvertently introduced through stocking of desired species c) No Asian carps introduced through illegal release of live adult fish d) Successfully partner with other Great Lakes agencies to prevent introduction or range expansion of Asian carps
<p>Goal II: Effectively share information to improve management and control of bighead, black, grass, and silver carps in Michigan</p>	<ul style="list-style-type: none"> a) All information materials developed as described in implementation table b) Asian Carps Task Group is functioning and active
<p>Goal III: Detect the presence of bighead, black, grass, and silver carps in Michigan</p>	<ul style="list-style-type: none"> a) eDNA surveillance approach is implemented as designed b) Public is informed and able to identify Asian carps c) Scientific collector's permit holders are informed and able to identify Asian carps d) Agency survey crews are trained and vigilant e) Fish passage systems and weirs are monitored
<p>Goal IV: Gather population level data on Asian carps at areas where they have been detected in Michigan waters; measure response of Michigan fish populations to introduction of Asian carps</p>	<ul style="list-style-type: none"> a) Able to measure abundance / relative abundance of Asian carps in Michigan's waters where they are introduced / established with sufficient precision and accuracy to implement effective management strategies b) Able to document effects of introduced Asian carps on Michigan's fish populations with sufficient precision and accuracy to implement effective management strategies

Table 5. Continued.

Goal	Outcome
Goal V: Eradicate, contain, or manage populations of Asian carps if they become established in Michigan	<ul style="list-style-type: none"> a) No Asian carps (any life stage) are transferred within waters, or to new waters, through actions of DNRE sampling crews b) Actions related to barrier/fish passage operation, construction, removal, or maintenance activities are evaluated by DNRE staff. c) Commercial and recreational harvest are successfully employed in managing Asian carps established in Michigan waters (i.e.; populations are contained, significantly reduced, or eliminated) d) Physical removal operations implemented by Fisheries Division result in reducing abundance of Asian carps established in Michigan waters e) Chemical removal operations implemented by Fisheries Division result in reducing abundance of Asian carps established in Michigan waters (i.e., populations are significantly reduced or eliminated) f) New techniques are developed or implemented by Fisheries Division that result in reducing abundance of Asian carps established in Michigan waters

8) APPENDICES

A) Acronyms used in this report

ACWG – (Federal) Asian Carp Working Group
ACTG – (proposed State of Michigan) Asian Carps Task Group
AIS – Aquatic invasive species
APHIS – Animal Plant Health and Inspection Service (U.S. Department of Agriculture)
ASRA – Aquatic Species and Regulatory Affairs Unit (within DNRE)
CAC – Center for Aquatic Conservation (University of Notre Dame)
DNRE – Department of Natural Resources and Environment (Michigan)
DNR – Department of Natural Resources (general)
eDNA – Environmental DNA
IFR – Institute for Fisheries Research (DNRE, Fisheries Division)
ISAC – Invasive Species Advisory Council
GIS – Geographic information system
GLFC – Great Lakes Fishery Commission
GLRI – Great Lakes Restoration Initiative
HACCP – Hazard Analysis and Critical Control Point
MDA – Michigan Department of Agriculture
MDCH – Michigan Department of Community Health
MDNR – Michigan Department of Natural Resources
NANPCA – Nonindigenous Aquatic Nuisance Prevention and Control Act
NOAA – National Oceanic and Atmospheric Administration
NREPA – Natural Resources and Environmental Protection Act
OGL – Office of the Great Lakes (DNRE)
SCP – Scientific collector’s permit
USACOE – United States Army Corps of Engineers
USEPA – United States Environmental Protection Agency
USFS – United States Forest Service
USGS – United States Geological Survey
USFWS – United States Fish and Wildlife Service
VHS – Viral hemorrhagic septicemia

B) Common and scientific names of fish mentioned in this report

Common name	Scientific name
alewife	<i>Alosa pseudoharengus</i>
bighead carp	<i>Hypophthalmichthys nobilis</i>
bigmouth buffalo	<i>Ictiobus cyprinellus</i>
black carp	<i>Mylopharyngodon piceus</i>
brook silverside	<i>Labidesthes sicculus</i>
channel catfish	<i>Ictalurus punctatus</i>
Chinook salmon	<i>Oncorhynchus tshawytscha</i>
common carp	<i>Cyprinus carpio</i>
emerald shiner	<i>Notropis atherinoides</i>
freshwater drum	<i>Aplodinotus grunniens</i>
gizzard shad	<i>Dorosoma cepedianum</i>
goldfish	<i>Carassius auratus</i>
grass carp	<i>Ctenopharyngodon idella</i>
lake sturgeon	<i>Acipenser fulvescens</i>
lake whitefish	<i>Coregonus clupeaformis</i>
largescale silver carp	<i>Hypophthalmichthys harmandi</i>
muskellunge	<i>Esox masquinongy</i>
redhorse	<i>Moxostoma species</i>
sea lamprey	<i>Petromyzon marinus</i>
silver carp	<i>Hypophthalmichthys molitrix</i>
spotfin shiner	<i>Cyprinella spiloptera</i>
walleye	<i>Sander vitreus</i>
yellow perch	<i>Perca flavescens</i>

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