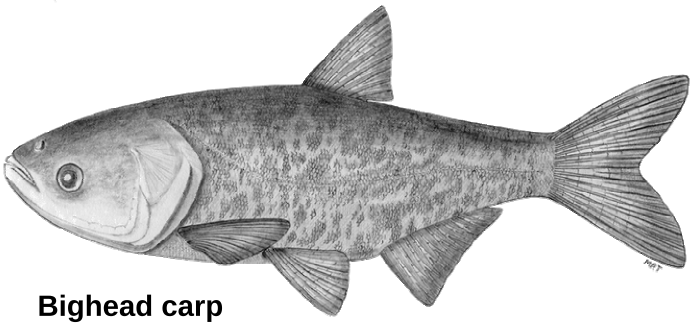
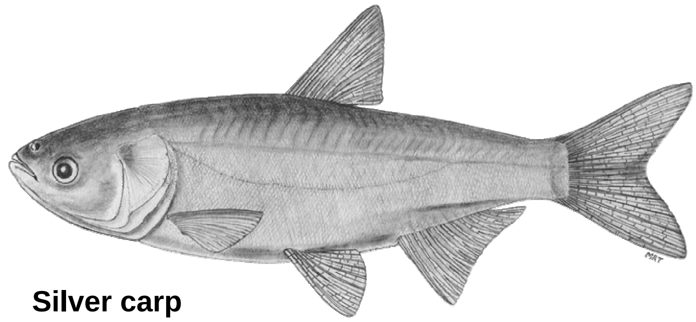


**Bighead carp**

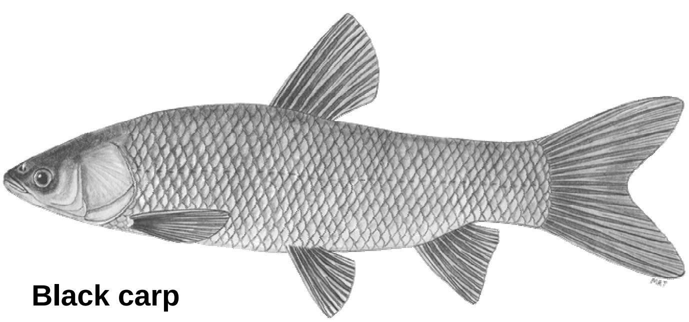


**Silver carp**

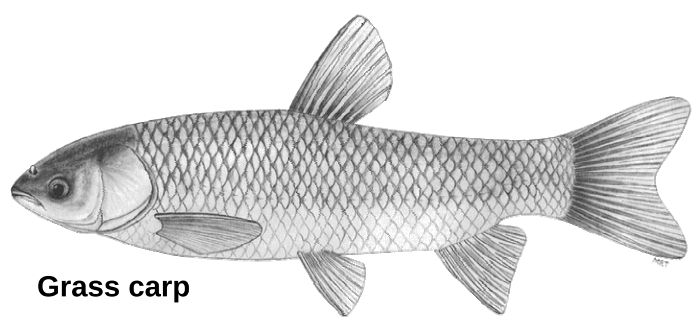
# ***<u>Draft</u>*** **Management and Control Plan for Asian Carps in the United States**

*Submitted to the Aquatic Nuisance Species Task Force*
*Prepared by the Asian Carp Working Group*

**April 2006**



**Black carp**



**Grass carp**

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Greg Conover
Chair, Asian Carp Working Group

# EXECUTIVE SUMMARY

There are many carps native to Asia, including seven that have been introduced to the United States. For the purposes of this document the term "Asian carps" refers to four species: black carp (*Mylopharyngodon piceus*), bighead carp (*Hypophthalmichthys nobilis*), grass carp (*Ctenopharyngodon idella*), and silver carp (*H. molitrix)*. Feral bighead, grass, and silver carps have all established reproducing populations in several major rivers of the United States. To date, there have been six confirmed collections of adult black carp by commercial fishers in the United States and unconfirmed reports of repeated captures of adult black carp in the Mississippi River and its tributaries over the past 13 years (Nico et al. 2005). There have been no collections of black carp eggs and larvae or observations of spawning (Nico et al. 2005).

The U.S. Fish and Wildlife Service (USFWS) contracted for the completion of risk assessments by the U.S. Geological Survey (USGS) that analyzed the probability and consequences of a species becoming established in the United States. Using risk assessment methods described by the Risk Assessment and Management Committee (1996), the USGS concluded that the organism risk potentials for bighead, black, and silver carps are all high (i.e., an unacceptable risk; Kolar et al. 2005; Nico et al. 2005). A national risk assessment for grass carp has not been completed and state-level risk assessments may still be needed where grass carp have not been reported or where the species has not become established.

The life history traits of Asian carps (e.g., reproductive capability, population densities, feeding habits, broad climate tolerance, mobility, and longevity) indicate that these four species have a high probability of causing ecological and economic effects where populations become established (Mandrak and Cudmore 2004; Kolar et al. 2005; Nico et al. 2005). In some locations of the Mississippi River Basin, such effects have occurred. Natural resources managers are concerned that Asian carps have the potential to cause extensive and irreversible changes to the aquatic environment, thereby jeopardizing the long-term sustainability of native aquatic species, particularly to imperiled, threatened, and endangered species. Confounding this situation is the fact that the bighead carp has been cultured and sold as a live food fish product since the early 1980s, grass carp have been stocked nationally by public and private entities since the late 1960s as a biological control for aquatic weeds (grass carp are also cultured and sold as a live food fish product), and the black carp has been used since the early 1980s as a biological control for pest snails in commercial aquaculture production ponds.

The USFWS recognized the complexity of the situation and that the potential magnitude of the problems were such that all stakeholders (i.e., private and public sector fisheries professionals, aquaculturists, aquatic ecologists, and the public) must be involved in the development of an appropriate management plan. With this kind of collaborative effort in mind, the USFWS and the Aquatic Nuisance Species Task Force organized an Asian Carp Working Group (Working Group) to develop a comprehensive national Asian carp management and control plan. This document represents the culmination of that effort.

The Working Group agreed that the desired endpoint of the plan is the extirpation of Asian carps in the wild, except for non-reproducing grass carp within planned locations [i.e., areas where nuisance aquatic vegetation can be controlled using planned introductions of sterile (triploid) fish contained within a designated area]. The Working Group was charged with developing a plan that first and foremost protects our Nation's natural resources. The Working Group was also charged with developing solutions that would allow for a viable aquaculture industry when implemented. Therefore, a framework for the responsible use of domestic stocks of Asian carps is described throughout this plan. It is in this context that the Working Group developed strategies and recommendations that address seven goals to protect the Nation's natural resources. This collaborative process was highly successful and nearly all issues were resolved. The Working Group developed 46 strategies and 129 recommendations to manage and control Asian carps (Table I, page viii). However, two issues were not resolved within the Working Group. In-depth discussions for these two issues are presented in Recommendation 3.1.15.10 *'Use of triploid black carp on aquaculture facilities'* and Recommendation 3.1.18.1 '*Commercial, domestic transport of live farm-raised bighead and grass carps.'*

Implementation of the plan should begin immediately to prevent further introduction and to stop the spread of Asian carps into uninvaded waters throughout the United States. There is much to learn regarding management and control of Asian carps and new information should be readily assimilated into the management framework so that strategies and recommendations can be refined as plan implementation proceeds. Estimated cost for implementation over a 20 year period is approximately $286 million. The amount of resources (e.g., staff, equipment, expertise, and funds) made available for plan implementation and how they are effectively integrated and efficiently used will largely determine the success of management and control efforts for Asian carps.

***Goal 1: Prevent accidental and deliberate unauthorized introductions of bighead, black, grass, and silver carps in the United States.*** Active control measures are needed to prevent introductions or range extensions; however, consideration must be given to the risks and costs/benefits to determine when actions are warranted. Strategies to manage 22 pathways for accidental or deliberate unauthorized introductions of Asian carps are presented within this plan. Working Group recommendations that address these potential pathways differ depending upon whether a particular species is absent, present without evidence of a reproducing population, or self-sustaining in the wild. Additional factors were considered for species in commercial trade (e.g. intended use).

***Goal 2: Contain and control the expansion of feral populations of bighead, black, grass, and silver carps in the United States.*** A long term, cooperative national effort between federal, state, tribal and private stakeholders is required to contain existing populations and prevent their spread. Such an effort will require a dedication of resources and manpower akin to those established for wildfire management and suppression or sea lamprey control in the Great Lakes. Monitoring programs are paramount in the timely detection and effective utilization of Rapid Response Plans to prevent range expansions and eradicate new introductions. Due consideration should be given to the effects of containment actions on the long-term ecological sustainability of native aquatic resources.

***Goal 3: Reduce feral populations of bighead, black, grass, and silver carps in the United States.*** Potential strategies for population reduction include: 1) enhancing commercial harvest through education, market research, gear development, and possibly financial incentives; 2) increasing recreational harvest; 3) biological controls (e.g., diseases, parasites, or predators); 4) release of sterile Asian carps to reduce the reproductive success and size of a target population; 5) release of transgenic Asian carps (including "Daughterless Carp" and Trojan technologies) developed to reduce the size of a target population via spread of a deleterious gene; 6) application of pheromones to enhance harvest or interfere with reproduction, recruitment, or other behaviors; 7) habitat or hydrologic modification to favor native fishes over Asian carps or to facilitate harvest of Asian carps; and 8) use of piscicides. To increase effectiveness, these potential strategies should be woven into an integrated management framework similar to the approach employed in the Great Lakes Sea Lamprey Control Program.

***Goal 4: Minimize potential adverse effects of feral bighead, black, grass, and silver carps in the United States.*** Once effects of feral Asian carps are accurately determined, it may be possible to minimize their undesirable effects by direct remediation of the effect. It should be recognized that such efforts treat the symptoms of the problem rather than removing the causative agent, nevertheless such strategies may be advisable if the populations of key or threatened species are affected. In addition to mitigative actions that enhance native populations and their habitats, education of boaters and other recreationists is needed to minimize effects of jumping silver carp.

***Goal 5: Provide information to the public, commercial industries, and government agencies to improve effective management and control of bighead, black, grass, and silver carps in the United States.*** An effective, nationally coordinated educational initiative is needed to: 1) identify specific needs for information and education; 2) identify the most effective approaches to reach and affect each group; 3) gather and validate the credibility of materials; 4) become both partners and leaders in planning, implementing, and evaluating education initiatives; and 5) identify gaps in knowledge or needs that can be addressed by applied or adaptive research. For greatest effectiveness, each component of an educational program should be developed in a stakeholder participatory process, monitored, evaluated, and adaptively managed.

***Goal 6: Conduct research to provide accurate and scientifically valid information necessary for the effective management and control of bighead, black, grass, and silver carps in the United States.*** A fundamental understanding of Asian carp biology and life history requirements underpins nearly all other areas of potential research to manage and control these species. Concurrent development of effective sampling gears and physical, chemical, or biological controls are required to reliably determine the relative abundance of Asian carp species and the potential for population reductions or eradication. The ecological and economic effects of past and potential introductions of Asian carps need to be verified and quantified to inform managers, stakeholders, and the general public of the importance in preventing further introductions. Research is needed to identify and evaluate economically and ecologically safe alternatives to Asian carps. Identifying viable alternatives to black carp for snail control in aquaculture ponds is the highest research priority identified by the Working Group. Research is also needed to find ways to ensure that any future use of Asian carps is low risk (i.e., low likelihood of escape and low consequence of escape).

***Goal 7: Effectively plan, implement, and evaluate the management and control of bighead, black, grass, and silver carps in the United States.*** Bighead, grass, and silver carps have established feral populations over a wide geographic range in the United States; therefore, a nationally coordinated approach is needed to successfully implement an effective integrated management plan. Implementation of an effective plan to address such a complex issue over such a wide geographic area will require a sophisticated management structure and significant funding. Efficient use of this funding will require that recommendations be strategically prioritized and properly sequenced. Formal institutional arrangements, including a process for conflict resolution, will also be required between partners to facilitate plan implementation.

**Table I.** Summary of all Strategies and Recommendations, by Goal, developed by the Working Group for managing and controlling Asian carps in the United States.

| **Goal 1: Prevent accidental and deliberate unauthorized introductions of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.1.1. Take actions to prevent the collection, transport, release, and improper disposal of Asian carps that may be intermixed with live wild-harvested baitfish.** | |
| 3.1.1.1. Assist states develop, promulgate, and enforce regulations that manage the harvest, transport, import, trade, and release of live wild-harvested aquatic bait. | Bighead, Black, Grass, Silver |
| 3.1.1.2. Develop and provide information to commercial and recreational baitfish harvesters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.2. Take actions to prevent the stocking of diploid Asian carps into non-aquaculture waters for biological control.** | |
| 3.1.2.1. Encourage states to develop regulations that prohibit the stocking of any diploid Asian carps into non-aquaculture waters for biological control. | Bighead, Black, Grass, Silver |
| 3.1.2.2. Remove or contain diploid Asian carps that have been previously stocked into non-aquaculture waters for biological control. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.3. Take actions to prevent illegal sale, shipping, and stocking of diploid grass carp as triploid grass carp.** | |
| 3.1.3.1. Encourage states that allow the legal importation of grass carp to adopt consistent, uniform regulations that allow only certified triploid grass carp to be shipped or stocked. | Grass |
| 3.1.3.2. Encourage states to conduct routine and random inspections of all live grass carp shipments within the state. | Grass |
| 3.1.3.3. Encourage the USFWS to provide ploidy determination for states conducting inspections of grass carp shipments. | Grass |
| **Strategy 3.1.4. Take actions to prevent the shipment of live black carp in grass carp shipments.** | |
| **Strategy 3.1.5. Take actions to address stocking triploid Asian carps into non-aquaculture waters for biological control.** | |
| 3.1.5.1. Encourage states to prohibit stocking triploid bighead, black, and silver carps for biological control in non-aquaculture waters. | Bighead, Black, Silver |
| 3.1.5.2. Encourage states to allow stocking triploid grass carp for biological control in non-aquaculture waters only within watersheds where grass carp are already present in the wild. | Grass |
| 3.1.5.3. Remove or contain triploid Asian carps that have been previously stocked in non-aquaculture waters within watersheds where the fish are not currently self-sustaining in the wild. | Bighead, Grass, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| **Strategy 3.1.6. Take actions to ensure that stocking triploid grass carp for biological control does not result in accidental or deliberate unauthorized introductions of diploid grass carp.** | |
| 3.1.6.1. The USFWS should seek an independent scientific review and evaluation of the Triploid Grass Carp Inspection and Certification Program. | Grass |
| 3.1.6.2. Develop and provide information on the USFWS Triploid Grass Carp Inspection and Certification Program. | Grass |
| **Strategy 3.1.7. Take actions to prevent the transport and release of Asian carps by boats, barges, and ships.** | |
| 3.1.7.1. Investigate fully the risks associated with ballast water transfers or other means of water transfer by barges and ships, and live well transfers by boats. | Bighead, Black, Grass, Silver |
| 3.1.7.2. Inform boaters, barge operators, and others of the risks of moving infested water and encourage voluntary actions to reduce this risk. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.8. Take actions to prevent the unintentional transport, release, or disposal of Asian carps by natural resources managers during management activities.** | |
| 3.1.8.1. Natural resources managers should employ pathway management tools, such as Hazard Analysis and Critical Control Point planning in the review of Standard Operating Procedures, to prevent introductions of Asian carps through natural resources management related pathways. | Bighead, Black, Grass, Silver |
| 3.1.8.2. Develop and provide information to natural resources managers and field staff that will help prevent unintentional introductions and spread of feral Asian carps. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.9. Take actions to prevent the importation of bighead, black, grass, and silver carps into the United States for "non-commercial use" (e.g., Internet sales and direct shipments from foreign sources to end users).** | |
| 3.1.9.1. Prohibit international importation of Asian carps for non-commercial use under federal and state regulations, except for research purposes under a controlled permit. | Bighead, Black, Grass, Silver |
| 3.1.9.2. Inform USFWS Law Enforcement Officers, other federal inspectors, and state conservation law enforcement officers about laws that apply to the import of live Asian carps, the importance of preventing the illegal import of Asian carps, and Asian carp identification. | Bighead, Black, Grass, Silver |
| 3.1.9.3. Inform potential importers of applicable state and federal laws and associated risks with international shipments of live Asian carps. | Bighead, Black, Grass, Silver |
| 3.1.9.4. Increase the numbers of trained USFWS Law Enforcement Officers and increase physical inspections of international shipments of live fish and eggs at designated or non-designated ports of entry. | Bighead, Black, Grass, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| **Strategy 3.1.10. Take actions to prevent the illegal importation and prohibit the legal importation of live bighead, black, grass, and silver carps for commercial use in the United States.** | |
| 3.1.10.1. Develop federal and state regulations that prohibit importations of live bighead, black, grass, and silver carps for commercial use in the United States. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.11. Take action to prevent the incidental inclusion of live Asian carps in international imports with other fishes.** | |
| **Strategy 3.1.12. Take actions to prevent the unintentional escape, release, or improper disposal of Asian carps from aquaculture facilities at poorly sited locations.** | |
| 3.1.12.1. Urge the development and enforcement of state regulations that prohibit the production of Asian carps at poorly sited facilities. | Bighead, Black, Grass, Silver |
| 3.1.12.2. Develop and provide information to Asian carp producers and growers that will help upgrade poorly sited facilities such that they are no longer high-risk to contain farm-raised carps and prevent accidental introductions. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.13. Develop an active research initiative to identify alternatives to the use of Asian carps.** | |
| 3.1.13.1. Form a coordinating research group that includes representatives from the aquaculture industry, the ethnic retail grocer industry, marketing scientists and developers, and aquaculture scientists to focus research efforts on the highest priority alternatives to the use of Asian carps. | Bighead, Black, Grass, Silver |
| 3.1.13.2. Develop an information module on economic and effective alternatives to replace the use of bighead and black carps on aquaculture facilities. | Bighead, Black |
| **Strategy 3.1.14. Take actions to prevent the incidental inclusion of Asian carps in aquaculture shipments of other farm-raised species to non-aquaculture waters.** | |
| 3.1.14.1. Review Standard Operating Procedures and recommend Best Management Practices that include requirements for suppliers and purchasers to conduct inspections of fish prior to shipment and release. | Bighead, Black, Grass |
| 3.1.14.2. Encourage states to develop regulations that allow for random inspections of live fish shipments into and within the state. | Bighead, Black, Grass |
| 3.1.14.3. Prohibit the use of surface waters containing Asian carps from being used in aquaculture facilities unless effective treatment is in place with a monitoring program. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.15. Reduce potential risks of continued use of Asian carps on properly sited aquaculture facilities to the environment.** | |
| 3.1.15.1. Review Standard Operating Procedures and develop Best Management Practices for “properly” sited aquaculture facilities. | Bighead, Black, Grass |
| 3.1.15.2. Encourage states to prohibit the use of grass carp on aquaculture facilities within watersheds where grass carp are not present in the wild. | Grass |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| 3.1.15.3. Encourage states to restrict the use of grass carp to certified triploids only on aquaculture facilities within watersheds where grass carp are present but not reproducing. | Grass |
| 3.1.15.4. States should encourage the use of only certified triploid grass carp on aquaculture facilities within watersheds where grass carp are self-sustaining in the wild. | Grass |
| 3.1.15.5. Verify functional sterility of triploid bighead carp and develop a triploid certification program for bighead carp. | Bighead |
| 3.1.15.6. Encourage states to prohibit the use of bighead carp on aquaculture facilities within watersheds where bighead carp are not self-sustaining in the wild. | Bighead |
| 3.1.15.7. Encourage states to restrict the use of bighead carp on aquaculture facilities within watersheds with self-sustaining populations to certified triploids only. | Bighead |
| 3.1.15.8. Encourage states to prohibit the use and production of silver carp on aquaculture facilities. | Silver |
| 3.1.15.9. Encourage states to prohibit the use and production of diploid black carp on aquaculture facilities. | Black |
| **3.1.15.10. *UNRESOLVED ISSUE:*** *Use of triploid black carp on aquaculture facilities.* | Black |
| **Strategy 3.1.16. Take actions to prevent the live transport of wild-caught Asian carps and potential introduction through release, improper disposal, or escape.** | |
| 3.1.16.1. Where legal for commercial or recreational fishers to possess Asian carps, encourage states to prohibit the possession of live wild-caught Asian carps. | Bighead, Black, Grass, Silver |
| 3.1.16.2. Review Standard Operating Procedures and actions of commercial fishers to identify Best Management Practices that reduce risks of live transport and introduction. | Bighead, Black, Grass, Silver |
| 3.1.16.3. Develop an information module and provide materials to commercial and recreational fishers and commercial live haulers that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.17. Take actions to prevent the release, escape, or improper disposal of domestic commercial shipments of live Asian carps.** | |
| 3.1.17.1. Require informational labeling of truck and invoice for shipments of Asian carps to avoid improper handling and potential introduction of fish that may be involved in an accident (e.g., "Nonnative fish: Unauthorized release prohibited"). | Bighead, Grass |
| 3.1.17.2. Review Standard Operating Procedures and develop Best Management Practices for fish haulers regarding containment and water transfer. | Bighead, Grass |
| 3.1.17.3. Prohibit the use of water from natural water bodies for water exchange during transport. | Bighead, Black, Grass |
| 3.1.17.4. Investigate improvements for containment methods on trucks carrying Asian carps. | Bighead, Black, Grass |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| 3.1.17.5. Develop an information module and provide materials to commercial transporters of live farm-raised Asian carps that will help prevent accidental and deliberate unauthorized introductions. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.18. Reduce the potential risk to the environment from continued commercial, domestic transport of live farm-raised Asian carps.** | |
| **3.1.18.1. *UNRESOLVED ISSUE:*** *Commercial, domestic transport of live farm-raised bighead and grass carps.* | Bighead, Grass |
| **Strategy 3.1.19. Take actions to prevent the accidental and deliberate unauthorized release of Asian carps by individuals.** | |
| 3.1.19.1. Encourage states to prohibit the sale, live transport, and unauthorized release of live Asian carps for non-commercial uses. | Bighead, Black, Grass, Silver |
| 3.1.19.2. Encourage states that allow sales of live Asian carps for human consumption to require retail grocers to kill the fish using prescribed humane methods, immediately upon sale. | Bighead, Grass |
| 3.1.19.2. Encourage states that allow sales of live Asian carps for human consumption to require retail grocers to kill the fish using prescribed humane methods, immediately upon sale. | Bighead, Grass |
| 3.1.19.3. Use educational campaigns such as Habitattitude$_{TM}$ to convey messages to the public that they should not release live Asian carps. | Bighead, Black, Grass, Silver |
| 3.1.19.4. Develop an information module and provide materials to producers, growers, marketers, and foodfish consumers of live Asian carps that will help prevent accidental and deliberate unauthorized introductions. | Bighead, Grass |
| **Strategy 3.1.20. Take actions to prevent the release, escape, or improper disposal of Asian carps by aquarium/hobby industry importers, wholesalers, and retailers.** | |
| 3.1.20.1. Encourage states to prohibit the trade of Asian carps for aquaria and hobby purposes. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.21. Prevent the release, escape, or improper disposal of live Asian carps via education facilities and projects, including schools, public aquaria, and research facilities.** | |
| 3.1.21.1. Urge states to develop and enforce regulations to reduce risks associated with the possession and disposal of Asian carps for research and exhibition purposes. | Bighead, Grass |
| 3.1.21.2. Develop an information module and provide materials to the academic and research communities that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | Bighead, Black, Grass, Silver |
| **Strategy 3.1.22. Take action to prevent the transport and release of adult sized (non-baitfish) Asian carps by boaters, anglers, and bowfishers.** | |
| 3.1.22.1. Develop an information module and provide materials to recreational fishers and boaters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | Bighead, Black, Grass, Silver |

**Table I.** Continued.

| **Goal 2: Contain and control the expansion of feral populations of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.2.1. Develop a national strategy and guidelines for science-based decision making concerning the need for continued and additional containment measures.** | |
| 3.2.1.1. Develop a Decision Support System to assist natural resources managers in prioritizing specific locations for the construction, maintenance, monitoring, or removal of barriers to carp dispersal. | Bighead, Black, Grass, Silver |
| 3.2.1.2. Evaluate the effectiveness afforded by alternative technical containment measures (i.e., physical and behavioral barriers). | Bighead, Black, Grass, Silver |
| 3.2.1.3. Promote, support, and provide technical analysis and comment for the field testing of novel containment methods. | Bighead, Black, Grass, Silver |
| 3.2.1.4. Anticipate and address consequences of specific containment actions on native biological communities. | Bighead, Black, Grass, Silver |
| **Strategy 3.2.2. Take immediate actions to prevent interbasin transfers and limit intrabasin movements of feral Asian carps populations.** | |
| 3.2.2.1. Develop and implement redundant barrier systems within the Chicago Sanitary and Ship Canal to limit the unrestricted access of Asian carps to Lake Michigan. | Bighead, Silver |
| 3.2.2.2. Develop and implement reasonable and effective measures that prevent the spread of Asian carps via canals, water ways, or other water diversions between basins. | Bighead, Black, Grass, Silver |
| 3.2.2.3. Construct and operate a Sound Projector Array-based acoustic bubble curtain fish deterrent at two locks and dams on the Upper Mississippi River to prevent the spread of Asian carps throughout the basin. | Bighead, Silver |
| 3.2.2.4. Identify additional containment measures needed to limit intrabasin movements of feral populations of Asian carps within the Mississippi River and other basins where established. | Bighead, Black, Grass, Silver |
| **Strategy 3.2.3. Minimize the range expansion and ecological effects of feral populations of Asian carps in conjunction with management actions to enhance aquatic environments for the sustainability of native biological communities.** | |
| 3.2.3.1. The USFWS and other natural resources management agencies should provide technical assistance and biological information to the USACE and participate in collaborative planning of fish passage structures. | Bighead, Black, Grass, Silver |
| 3.2.3.2. Require federal and state agencies to consider the potential range expansion and ecological effects of Asian carps when designing or reviewing water control structure projects and permits. | Bighead, Black, Grass, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| **Strategy 3.2.4. Forecast, detect, and rapidly respond to new feral Asian carp introductions and range expansions.** | |
| 3.2.4.1. Develop an early detection Decision Support System to: 1) identify high risk locations susceptible to introductions or range expansions of Asian carps, 2) identify watersheds of special concern, 3) prioritize specific locations for implementing comprehensive early detection monitoring programs. | Bighead, Black, Grass, Silver |
| 3.2.4.2. Adopt and/or adapt an Incident Command System to provide for national coordination and management of early detection and rapid response programs. | Bighead, Black, Grass, Silver |
| 3.2.4.3. Develop and conduct routine early detection monitoring programs in locations where risk of introductions or range expansions of Asian carps exists. | Bighead, Black, Grass, Silver |
| 3.2.4.4. Develop Rapid Response Plans that identify where rapid response actions can effectively eradicate Asian carps and how those actions will be carried out. | Bighead, Black, Grass, Silver |
| **Strategy 3.2.5. Develop a system for notifying management and regulatory agencies of escapees from captive populations of Asian carps.** | |
| 3.2.5.1. Develop a database and communication network with agencies that regulate Asian carp possession. | Bighead, Black, Grass, Silver |
| 3.2.5.2. Create an information sharing system with early detection monitoring and rapid response project managers. | Bighead, Black, Grass, Silver |
| **Strategy 3.2.6. Develop an information exchange network for agencies, organizations, and partners to communicate and share "real time" data to facilitate early detection and rapid response programs.** | |
| 3.2.6.1. Develop a website and centralized databases to provide information on early detection and rapid response programs. | Bighead, Black, Grass, Silver |
| 3.2.6.2. Develop a list-server to provide a forum for information exchange. | Bighead, Black, Grass, Silver |
| 3.2.6.3. Utilize and support the Nonindigenous Aquatic Species Information Center for accurate and spatially referenced biogeographic information and the Nonindigenous Aquatic Species Alert System to track expansion. | Bighead, Black, Grass, Silver |

| **Goal 3: Reduce feral populations of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.3.1. Determine life history characteristics and build population dynamics models of Asian carps in the Mississippi River Basin.** | |
| 3.3.1.1. Determine life history parameters of Asian carps in the Mississippi River Basin. | Bighead, Black, Grass, Silver |
| 3.3.1.2. Create population, biomass, and recruitment models for Asian carps. | Bighead, Grass, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| **Strategy 3.3.2. Increase the commercial harvest of Asian carps.** | |
| 3.3.2.1. Evaluate gear and harvest method effectiveness, develop new gears if necessary, and provide information to commercial fishers. | Bighead, Silver |
| 3.3.2.2. Increase the number of commercial fishers. | Bighead, Silver |
| 3.3.2.3. Examine commercial fishing regulations and consider changes to increase harvest. | Bighead, Silver |
| 3.3.2.4. Provide financial incentives to commercial fishers to increase harvest of Asian carps. | Bighead, Silver |
| 3.3.2.5. Develop new markets for Asian carps. | Bighead, Grass, Silver |
| 3.3.2.6. Determine contaminant concentrations in edible portions of feral Asian carps. | Bighead, Grass, Silver |
| **Strategy 3.3.3. Increase recreational harvest of Asian carps.** | |
| 3.3.3.1. Examine recreational harvest regulations to eliminate barriers to recreational harvest of Asian carps. | Bighead, Grass, Silver |
| 3.3.3.2. Inform recreational fishers about Asian carp harvest and preparation methods. | Bighead, Grass, Silver |
| **Strategy 3.3.4. Reduce populations of Asian carps through the introduction of biological controls such as disease agents, parasites, or predators.** | |
| 3.3.4.1. Develop information on the factors that determine the efficacy of native predator enhancement to control Asian carps. | Bighead, Silver |
| **Strategy 3.3.5. Consider stocking sterile carp or monosex tetraploids to inhibit reproduction and recruitment of feral fish.** | |
| 3.3.5.1. Examine the potential efficacy of introduction of monosex tetraploid fish as a control method. | Bighead, Silver |
| **Strategy 3.3.6. Research and apply transgenic manipulations (e.g., “Daughterless carp” and “Trojan gene” technologies).** | |
| 3.3.6.1. Adapt “daughterless carp” genetic technology to Asian carps. | Bighead, Silver |
| **Strategy 3.3.7. Develop and apply pheromone baits to control Asian carps.** | |
| 3.3.7.1. Sex pheromone research should continue with the goal of production and application of field-applicable technologies. | Bighead, Silver |
| 3.3.7.2. Investigate aggregation pheromones for juvenile Asian carps. | Bighead, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
| --- | --- |
| **Strategy 3.3.8. Develop and apply habitat and hydrological manipulations that favor native species over Asian carps or that might be useful in harvest enhancement.** | |
| 3.3.8.1. Provide technical assistance and biological information to the USACE and participate in collaborative planning of habitat improvement projects (e.g., Navigation and Ecosystem Sustainability Program, Missouri River Mitigation Project, and other authorities). | Bighead, Silver |
| **Strategy 3.3.9. Investigate the sensitivity of Asian carps to piscicides, and examine the feasibility of chemical Asian carp control in specific habitats.** | |
| 3.3.9.1. Determine effectiveness of registered piscicides to control Asian carps. | Bighead, Black, Grass, Silver |
| 3.3.9.2. Identify conditions where rotenone or antimycin could be used to control populations of Asian carps. | Bighead, Black, Grass, Silver |
| 3.3.9.3. Determine potential of other chemicals to control Asian carps. | Bighead, Black, Grass, Silver |
| 3.3.9.4. Determine feasibility and applicability of piscicide bait deployment to control black and grass carps. | Black, Grass |
| 3.3.9.5. Determine registration needs, if any, for the use of piscicides to control Asian carps, and ensure that piscicides are available for appropriate uses. | Bighead, Black, Grass, Silver |

**Goal 4: Minimize potential adverse effects of feral bighead, black, grass, and silver carps in the United States.**

| Strategies and Recommendations | Species |
| --- | --- |
| **Strategy 3.4.1. Enhance organisms adversely affected by Asian carps.** | |
| 3.4.1.1. Monitor populations of species most likely to be affected by Asian carps. | Bighead, Black, Grass, Silver |
| 3.4.1.2. Restore or supplement numbers of native species through direct release (i.e., stocking). | Bighead, Black, Grass, Silver |
| 3.4.1.3. Protect or restore native species through methods other than stocking. | Bighead, Black, Grass, Silver |
| **Strategy 3.4.2. Minimize damage to waterway users that results from silver carp.** | |
| 3.4.2.1. Inform and train boaters to avoid damage from jumping silver carp. | Silver |

**Table I.** Continued.

| **Goal 5: Provide information to the public, commercial industries, and government agencies to improve effective management and control of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.5.1. Understand the specific information needs and the most effective approaches to reach and affect desired results with each key audience.** | |
| 3.5.1.1. Engage potential key audiences in the development of a comprehensive education and outreach program. | Bighead, Black, Grass, Silver |
| **Strategy 3.5.2. Prepare science-based materials based on key audience needs that can be used to develop curricula for effective education and outreach programs.** | |
| 3.5.2.1. Develop an information module that defines and describes Asian carps, efforts to contain and reduce feral populations, and sources from which to learn more about these fishes. | Bighead, Black, Grass, Silver |
| 3.5.2.2. Develop an information module on the United States' Asian carp industry, size, scope, economics, and current farming practices. | Bighead, Black, Grass, Silver |
| 3.5.2.3. Develop an information module on potential effects of Asian carps and reasons to contain and reduce their feral populations. | Bighead, Black, Grass, Silver |
| 3.5.2.4. Develop an information module on the identification of all life stages of Asian carps. | Bighead, Black, Grass, Silver |
| 3.5.2.5. Develop an information module on why and how to report sightings of Asian carps. | Bighead, Black, Grass, Silver |
| 3.5.2.6. Develop an information module on Hazard Analysis and Critical Control Point planning procedures. | Bighead, Black, Grass, Silver |
| 3.5.2.7. Develop an information module on the construction and maintenance of effective spillway barriers to reduce the risk of escape of Asian carps from private impoundments. | Bighead, Black, Grass |
| 3.5.2.8. Develop an information module to provide general information about regulations related to Asian carps. | Bighead, Black, Grass, Silver |

| **Goal 6: Conduct research to provide accurate and scientifically valid information necessary for the effective management and control of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.6.1. Assemble information about the distribution, biology, life history, and population dynamics of bighead, black, grass, and silver carps.** | |
| 3.6.1.1. Describe current and temporal changes in distribution to better understand the invasion and colonization process. | Bighead, Black, Silver |
| 3.6.1.2. Describe movements and distribution of Asian carps in waters of the United States (e.g., habitat preference, habitat selection, and habitats used). | Bighead, Black, Grass, Silver |

**Table I.** Continued.

| Strategies and Recommendations | Species |
|---|---|
| 3.6.1.3. Describe diets, evaluate food selection and availability, estimate food consumption, and assess feeding interactions (i.e., predation and competition) with native biota (trophic ecology). | Bighead, Black, Grass, Silver |
| 3.6.1.4. Assess ecologically important aspects of physiology and behavior such as environmental tolerances, endocrine functions, and sensory capabilities. | Bighead, Black, Grass, Silver |
| 3.6.1.5. Estimate key population variables such as mortality, emigration and immigration, growth rates, fecundity, and stock-recruitment relations for population modeling. | Bighead, Black, Grass, Silver |
| **Strategy 3.6.2. Develop effective sampling and control methods for all life stages of Asian carps in both standing and flowing water environments.** | |
| 3.6.2.1. Develop and evaluate effective methods for sampling feral populations of Asian carps. | Bighead, Black, Grass, Silver |
| 3.6.2.2. Develop and evaluate effective attractants and repellents. | Bighead, Silver |
| 3.6.2.3. Evaluate existing piscicides and, if necessary, develop new piscicides that are selective for Asian carps. | Bighead, Black, Silver |
| 3.6.2.4. Develop effective physical and behavioral barriers for controlling the movement of Asian carps. | Bighead, Black, Grass, Silver |
| 3.6.2.5. Evaluate the potential for commercial harvest of feral Asian carps to control their abundance in public waters. | Bighead, Black, Grass, Silver |
| **Strategy 3.6.3. Determine the demonstrated and probable ecological and economic effects of Asian carps in the United States and determine the degree to which these effects are negative.** | |
| 3.6.3.1. Assess the ecological effects of bighead, black, and silver carps on individual aquatic species and aquatic ecosystems. | Bighead, Black, Silver |
| 3.6.3.2. Document the actual ecological effects of bighead, black, grass, and silver carps. | Bighead, Black, Silver |
| 3.6.3.3. Conduct analyses of economic effects. | Bighead, Black, Grass, Silver |
| **Strategy 3.6.4. Develop economically viable and environmentally safe alternatives to the uses of farm-raised Asian carps.** | |
| 3.6.4.1. Evaluate ecologically safe and economically viable alternatives to black carp for snail control. | Black |
| 3.6.4.2. Characterize ethnic markets for live fish and for fresh fish on ice. Determine consumer preferences for various attributes including size, product form, and price. | Bighead, Black, Grass, Silver |
| 3.6.4.3. Evaluate the economic feasibility of growing and selling triploid bighead and grass carps for the live and fresh-on-ice markets. | Bighead, Grass |

**Table I.** Continued.

| **Goal 7: Effectively plan, implement, and evaluate the management and control of bighead, black, grass, and silver carps in the United States.** | |
|---|---|
| **Strategies and Recommendations** | **Species** |
| **Strategy 3.7.1. Develop an implementation program that effectively coordinates, oversees, and drives implementation efforts.** | |
| 3.7.1.1. The Aquatic Nuisance Species Task Force should create a committee comprised of key partners and stakeholders with needed expertise and identify a lead agency to oversee the implementation of this plan. | Bighead, Black, Grass, Silver |
| 3.7.1.2. Develop institutional arrangements that formalize the roles and responsibilities of partner agencies and organizations in plan implementation. | Bighead, Black, Grass, Silver |
| 3.7.1.3. Integrate, sequence, and prioritize recommendations from among all sections of this plan. | Bighead, Black, Grass, Silver |
| 3.7.1.4. Seek "new" funds from various sources to implement this plan. | Bighead, Black, Grass, Silver |
| 3.7.1.5. Develop criteria and/or performance measures to evaluate the effectiveness of management and control efforts. | Bighead, Black, Grass, Silver |
| 3.7.1.6. Develop an adaptive management framework that allows the flexibility to readily change and adapt management strategies as knowledge is gained and techniques are refined or developed. | Bighead, Black, Grass, Silver |
| 3.7.1.7. Develop an effective strategy for communication and coordination among those implementing recommendations for management and control of Asian carps. | Bighead, Black, Grass, Silver |

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# CHAPTER 1. INTRODUCTION

## 1.1. Background

Freshwater aquatic animals have been identified as the most threatened group of species in the United States (Master et al. 1998). "One-third of the Nation's freshwater fish species are threatened or endangered, 72 percent of freshwater mussels are imperiled, and the number of threatened and endangered species has tripled in the last 20 years" (USFWS 2002). Non-native species are second only to habitat loss as a leading threat to native biodiversity in the United States (Wilcove et al. 1998). Aquatic systems are especially vulnerable, and invasions in these ecosystems are especially difficult to contain and reverse (FAO 1996). The increased understanding and concern over nonnative species are evidenced also in the aquaculture community. The National Aquaculture Association, an aquaculture industry trade association, recognizes the importance of environmental issues. The Association's web site (http://www.nationalaquaculture.org) includes pages addressing environmental stewardship issues related to water use, discharges from facilities, and nonnative animal introductions. Statements recognizing the facts that introductions, either intentional or unintentional, can cause significant harm are also included (National Aquaculture Association 2004).

Unintentional aquatic species introductions can have harmful, even catastrophic, environmental consequences (Courtenay and Stauffer 1984; Great Lakes Commission 1992; Fuller et al. 1999). Often, nonnative species cause a combination of economic, environmental, and health threats (National Invasive Species Council 2001; Lodge et al. 2006). In the Great Lakes alone, approximately 160 nonnative aquatic organisms have become established since the 1800s (Ricciardi 2001). Many of these species, including sea lamprey (*Petromyzon marinus*) and zebra mussels (*Dreissena polymorpha*), have had substantial economic and ecological effects (Great Lakes Commission 1992).

The Aquatic Nuisance Species Task Force (Task Force) is an intergovernmental entity established under the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (Act, 16 U.S.C. 4701-4741). The Task Force is co-chaired by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration and is responsible for coordination of national efforts to prevent the introduction and spread of aquatic nuisance species. Chief among these responsibilities is to develop national control programs for specific high-risk nuisance species. Key challenges that require urgent action include prevention, detection, eradication, and control, and the coordination of these efforts at all levels of government (Lodge et al. 2006). The Task Force determined that Asian carps are nuisance species that warrant active control by natural resources management agencies. To that end, the Task Force requested that the USFWS develop a national management and control plan for Asian carps. The USFWS Region 3 Fisheries Program was subsequently asked to develop the plan.

There are many carps native to Asia, including seven that have been introduced to the United States; however, the common usage of the term "Asian carps" in the United States has come to include four carps. These are the grass carp (*Ctenopharyngodon idella*), black carp (*Mylopharyngodon piceus*), bighead carp (*Hypophthalmichthys nobilis*), and silver carp (*H. molitrix)*. For the purposes of this document, the term "Asian carps" will be defined as these four species. Summaries of each of the four species of Asian carps including overviews of biology, introduction into the United States, present distribution and abundance, present uses, and potential adverse effects are presented in Chapter 2. This document does not consider common carp (*Cyprinus carpio*; introduced in the late 1800s) or goldfish (*Carassius auratus;* introduced in the 1600s) which are carps originating in Asia, and are established in North America, or the crucian carp (*Carassius carassius*), which has been introduced but is apparently extirpated.

Introductions of Asian carps into waters of the United States are the result of combinations of direct stockings by or authorized by various agencies, unauthorized stockings by private individuals, and unintentional escapes from university research facilities, federal and state agency facilities, and private aquaculture operations. Bighead, grass, and silver carps have all established reproducing populations in the United States. Adult black carp have been collected in the Mississippi River Basin, however there have been no collections of eggs and larvae or observations of spawning (Nico et al. 2005). Asian carps have the potential to disperse widely in open systems, potentially affecting waters beyond where the original introduction occurred. Due to the widespread distribution and migratory nature of Asian carps, state agencies must look beyond their borders and work together to be most effective when developing approaches and regulations to manage and control Asian carps. State-by-state programs will be less effective with these species.

The altered conditions of river ecosystems in the interior United States may have affected the ability of native fishes to compete with Asian carps in these waters. Most of the Mississippi River Basin has been modified extensively for commercial navigation, flood control, and other human uses. The Upper Mississippi River-Illinois Waterway System and floodplain ecosystem was described by the U.S. Army Corps of Engineers (USACE) Environmental Effect Statement (USACE 2004) as follows:

> "Prior to widespread European settlement of the region, the Upper Mississippi River System was a diverse landscape of tallgrass prairie, wetlands, savannas, and forests. Logging, agriculture, and urban development over the past 150 years have resulted in the present floodplain landscape that is more than 80 percent developed. Millions of acres of wetland drainage, thousands of miles of field tiles, road ditches, channelized streams, and urban storm water sewers accelerate runoff to the main stem rivers. The modern hydrologic regime is highly modified, with increased frequency and amplitude of changes in river discharge. Management to facilitate barge transport has occurred since the 1820's, and today a system of 43 locks, 37 dams and thousands of river channel training structures, including wing dams and revetments, and dredging maintain a permanent three meter deep channel for barge traffic. The modern basin landscape delivers large amounts of sediment, nutrients, and contaminants to the river. Since impoundment, sediment accumulation and littoral (i.e., wind and wave) processes in the navigation pools have greatly altered aquatic habitats."

The fish fauna of these rivers have undergone rapid change in response to habitat alterations (Pflieger 1997). For example, prior to these changes in habitat, native large river fishes such as paddlefish (*Polyodon spathula*) and sturgeons (*Acipenser* and *Scaphyrhynchus* spp.) traveled great distances to spawn over submerged gravel bars where their adhesive fertilized eggs are deposited and incubated (Russell 1986; Pflieger 1997). With the eventual dredging, straightening, and damming of the Mississippi River for navigation and flood control, most gravel bars required for spawning and incubation were removed. Other species such as speckled chub (*Macrhybopsis aestivalis*), sicklefin chub (*M. meeki*), and sturgeon chubs (*M. gelida*) are specialized for life in open, sandy or gravelly sections of the river channel and have nearly disappeared in some river reaches (Pflieger 1997). Dams block migrations of many species including paddlefish, Alabama shad (*Alosa alabamae*), and skipjack herring (*Alosa chrysochloris*). As a result the skipjack is nearly extirpated from Wisconsin, along with the ebony shell (*Fusconaia ebena*) and elephant ear (*Elliptio crassidens*), both state endangered mussels for which the skipjack is the sole host (Wisconsin Department of Natural Resources 2004).

Bighead, grass, and silver carps have become established in the altered habitats of the Mississippi River Basin while native large river fishes such as the paddlefish have struggled in this disturbed system. The floodplain system provides varied biophysical conditions for successful spawning, egg incubation, nursery and overwintering areas, and plentiful macrophytes, planktonic, detrital or molluskan food resources for Asian carps (Cudmore and Mandrak 2004; Kolar et al. 2005; Nico et al. 2005). In addition, a large segment (1,800 kilometers) of the mainstem Mississippi River is free flowing from St. Louis, Missouri to New Orleans, Louisiana. This allows for relatively unimpeded movement of Asian carps from the mouth of the Mississippi River to the Missouri and Ohio rivers. There is also sufficient passage through some locks and dams as well as sufficient distance, flow, and suitable temperatures to support egg incubation during the period of late May to late September (Nico et al. 2005).

In addition to the ability of introduced Asian carps to disperse throughout the Mississippi River and connected waterways, 22 potential pathways of introduction are identified within this plan. Each of these pathways could lead to additional introductions. Examples of such pathways include the production, live transport, and live sales of Asian carps in seafood markets; stocking Asian carps in private or public waters for biological control; the transport and release of baitfishes caught in the wild; live transport and intentional spread of Asian carps by commercial fishers; movement of Asian carps in ballast waters and live wells; and intentional releases of Asian carps by consumers, hobbyists, and animal rights activists (Higbee and Glassner-Shwayder 2004; Kolar et al. 2005).

Based on experiences with other nuisance species, natural resources management agencies, fishery and aquaculture scientists, and associated industries are concerned about the potential ecological and economic effects posed by feral populations of Asian carps. The life history traits of Asian carps (e.g., reproductive capability, population densities, feeding habits, broad climate tolerance, mobility, and longevity) indicate that these four species have a high probability of causing ecological and economic effects where populations become established (Mandrak and Cudmore 2004; Kolar et al. 2005; Nico et al. 2005). Environmental and economic impacts (damage and control costs) of aquatic nuisance species in the Great Lakes Basin alone were estimated at nearly $5.7 billion per year in 2005; approximately $4.5 billion of which is associated with fishery losses (i.e., reduced populations of important commercial and sport fishes; Pimentel 2005). The USFWS has estimated that the potential economic impact of zebra mussels to United States and Canadian water users within the Great Lakes region will total $5 billion between 2000 and 2009 (USGS 2000). Millions of dollars are spent each year on integrated, long-term control efforts such as the Sea Lamprey Control Program. The USFWS implements the integrated Sea Lamprey Control Program in United States' waters of the Great Lakes as a contracted agent of the Great Lakes Fishery Commission. The Great Lakes Fishery Commission (2005) and USFWS financial documents reported the costs for sea lamprey control, assessment, and research was nearly $17 million in 2005. Nuisance species have the potential to cause extensive and irreversible changes to the environment (USEPA 2005; Lodge et al. 2006), thereby jeopardizing the long-term sustainability and use of existing resources, particularly imperiled, threatened, and endangered species. Although concerns over feral populations of Asian carps in large river systems and their tributaries are most often noted, these fishes can survive and potentially affect interior small order streams and lakes. Fishing, hunting, boating, and other wildlife-associated recreation may be adversely affected by feral populations of bighead and silver carps (Kolar et al. 2005). The decline of native fishes important as sport and food species would adversely affect recreational angling and other industries that benefit from sport fishing, such as tourism (Kolar et al. 2005). The USFWS estimated that nationwide freshwater fishing expenditures by 28.4 million anglers totaled $21.3 billion in 2001 (U.S. Department of the Interior et al. 2002).

Confounding the Asian carp issue is the fact that three of the four species (bighead, black, and grass carps) have commercial applications and are in trade in the United States. The bighead carp has been cultured and sold as a live food fish product since the early 1980s, grass carp have been stocked nationally by public and private entities since the late 1960s as a biological control for nuisance aquatic weeds, (grass carp are also cultured and sold as a live food fish product), and the black carp has been used since the early 1980s as a biological control for pest snails in commercial aquaculture production ponds. Silver carp are *not* presently cultured in the United States, largely because of their jumping habits and poor handling qualities during production, harvest, and transport (Kolar et al. 2005).

The National Aquaculture Development Act, signed into law in 1980, stated that it is "in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States." This act indicated that the principal responsibility for the development of aquaculture lies with the private sector, but also assigned responsibility to the U.S. Department of Agriculture (USDA), U.S. Department of Commerce, and U.S. Department of Interior (16 U.S.C. 2801-2810; Public Law 96-362). This policy and the subsequent responsibilities remain in force.

The majority of private aquaculture facilities in the United States are classified as small businesses by the Small Business Administration (93% of baitfish farms, 84% of catfish farms, and 88% of foodfish businesses other than catfish and trout farms; USDA 1999). Much of the aquaculture in the United States occurs in impoverished rural areas such as parts of the Mississippi Delta region. The channel catfish (*Ictalurus punctatus*) industry was responsible, directly and indirectly, for 48% of the employment in Chicot County, Arkansas. This included $22 million in tax revenue and a total economic effect of over $384 million (Kaliba and Engle 2004). The 2002 Census of Agriculture reported that aquaculture of all organisms in the United States grew from a $45 million industry in 1974 to a $1.13 billion industry in 2002 (USDA 2004). This economic activity multiplies into a total economic effect of over $7.6 billion in the United States when feed mills, supply companies, processors, labor expenditures, and tax revenue are included. Both natural resource conservation and the aquaculture industry must be considered in the development of management and control plans for Asian carps.

As a first step in addressing Asian carp issues, the USFWS hosted an Asian Carp Workshop in St. Louis, Missouri, during April 2000. The purpose of that workshop was to initiate the process of gathering input for the development of a *Mississippi River Basin* Asian carp management and control plan. The goal of the workshop was to review the status, distribution, biology, ecological, and economic benefits and effects of Asian carps, and to identify management and control alternatives that may reduce or mitigate adverse effects (USFWS 2000). In 2002, the Task Force requested the USFWS develop a *national* management and control plan for Asian carps. In early 2004, the USFWS and Task Force organized an Asian Carp Working Group (Working Group) with broad and diverse representation from partners and stakeholders to participate in the collaborative development of the national management and control plan. Asian carp and nuisance species management specialists representing federal, state, tribal, and

Canadian natural resources management agencies, and experts from universities and research facilities, aquaculturists and their trade association representatives, and non-governmental organizations are members of the Working Group. (See pages i-ii for a list of Working Group members and affiliations.)

In May 2004, the USFWS hosted an initial Working Group meeting in Columbia, Missouri, that built upon the Workshop held in 2000. The purpose of the meeting was to begin a collaborative process to develop an integrated, *national* management and control plan for Asian carps. Breakout sessions conducted during the meeting focused discussions on the issues of preventing spread, detection and monitoring, population control and abatement, and research and information exchange. Working Group members were invited to participate on drafting teams (Appendix 6.1) to develop the strategies, initiatives, and actions identified during the meeting into an integrated national management and control plan. In August 2005, Working Group members met in Nashville, Tennessee, to review and discuss a first draft of the management and control plan.

This collaborative process was highly successful and nearly all issues were resolved. The Working Group developed 46 strategies and 129 recommendations to manage and control Asian carps (presented in Chapter 3). However, two issues were not resolved within the Working Group. In-depth discussions for these two issues are presented in Recommendation 3.1.15.10 *'Use of triploid black carp on aquaculture facilities'* (page 50), and Recommendation 3.1.18.1 '*Commercial, domestic transport of live farm-raised bighead and grass carps'* (page 59).

## 1.2. Goals

The Working Group agreed that the desired endpoint of the plan is the extirpation of Asian carps in the wild, except for non-reproducing grass carp within planned locations [i.e., areas where nuisance aquatic vegetation can be controlled using planned introductions of sterile (triploid) fish contained within a designated area]. The Working Group was charged with developing a plan that first and foremost protects our Nation's natural resources. The Working Group was also charged with developing solutions that would allow for a viable aquaculture industry when implemented. Therefore, a framework for the responsible use of domestic stocks of Asian carps is described throughout this plan. It is in this context that the Working Group developed strategies and recommendations that address seven goals to protect the Nation's natural resources. The Strategies and Recommendations developed by the Working Group to accomplish each of the following seven goals are discussed in detail in Chapter 3 and are summarized in Chapter 4 (Table 4.1, page 115) with a subjective estimate of the cost to independently implement each action.

1. Prevent accidental and deliberate unauthorized introductions of bighead, black, grass, and silver carps in the United States.

2. Contain and control the expansion of feral populations of bighead, black, grass, and silver carps in the United States.

3. Reduce feral populations of bighead, black, grass, and silver carps in the United States.

4. Minimize potential adverse effects of feral bighead, black, grass, and silver carps in the United States.

5. Provide information to the public, commercial industries, and government agencies to improve effective management and control of bighead, black, grass, and silver carps in the United States.

6. Conduct research to provide accurate and scientifically valid information necessary for the effective management and control of bighead, black, grass, and silver carps in the United States.

7. Effectively plan, implement, and evaluate the management and control of bighead, black, grass, and silver carps in the United States.

# CHAPTER 2. SPECIES OVERVIEWS

This chapter presents an overview of the biology, introduction into the United States, present distribution and abundance, present uses, and potential adverse effects of each of the four species of Asian carps. The action plan for managing and controlling Asian carps is presented in Chapter 3.

## 2.1. Bighead Carp

### 2.1.1 Biology

The bighead carp (Figure 2.1.1) is large, deep-bodied, and can grow to lengths of 1.5 m and weights of 40 kg (Laird and Page 1996). It has a very large head, a large toothless mouth, and eyes located far forward and low on the head well below the axis of the body (Lin 1991). Coloration of the body is dark gray above and cream-colored below with dark gray to black irregular blotches on the back and sides (Kolar et al. 2005).

**Figure 2.1.1.** Bighead carp. Photo courtesy of USFWS, Carterville Fishery Resources Office.

Bighead carp are native to eastern China's large lowland rivers, preferring temperatures between 4-26$^{o}$C. The species is known to school and occupy the upper to middle layers of the water column. They are extremely hardy and can readily adapt to many temperate freshwater environments. Juvenile bighead carp have been reported in low-velocity and off-channel habitats in the Missouri, Mississippi, Wabash, and lower Ohio rivers (Kolar et al. 2005).

The bighead carp feeds in benthic, mid-water, and surface environments; feeding primarily on zooplankton, but also consuming large quantities of blue-green algae, aquatic insects (adults and larvae), and detritus (Robison and Buchanan 1988). Gill rakers are long, comb-like and close-set, allowing it to strain planktonic organisms from the water for food. Bighead carp lack a true stomach which requires them to feed almost continuously (Henderson 1976).

Female bighead carp reach sexual maturity at three years of age with a body weight of 7-10 kg, while males can reach sexual maturity in two years with a body weight of 5-8 kg; however, this varies significantly with changing environmental conditions (Huet 1970; Kolar et al. 2005). Spawning activity is associated with high spring flows (Verigin et al. 1978), and spawning areas have high water velocity (0.6-2.3 m/s), turbid water, and water temperature in the range of 18-30°C (Kolar et al. 2005). Bighead carp produce eggs that are semi-buoyant and require current to keep them from sinking to the bottom (Soin and Sukhanova 1972; Pflieger 1997). Floodplains associated with rising water levels provide nursery areas for larvae and juvenile forms (Huet 1970). Fecundity increases with age and body weight and is directly related to growth rate (Verigin et al. 1990). Vinogradov et al. (1966) found that first-time spawners average 288,000 eggs, while Sukhanova (1966) and Jennings (1988) documented egg production to range from 478,000-1,100,000, respectively.

### 2.1.2. Introduction to the United States

Bighead carp were first brought into the United States in 1972 by a private fish farmer in Arkansas as a potential biological control agent to improve water quality and increase fish production in culture ponds (Nico and Fuller 2005a). Universities and state agencies conducted research on bighead carp for a number of years. Bighead carp have been stocked for research purposes in Arkansas (Jennings 1988), Alabama (Pretto 1976; Dunseth 1977; Cremer and Smitherman 1980), Illinois (Buck et al. 1978a, 1978b, 1981), South Carolina (Wilson et al. 1984), Texas (Bettoli et al. 1985; McBride 1997), and Colorado (Lieberman 1996). Henderson and Wert (1976), in a document prepared for the U.S. Environmental Protection Agency (USEPA), stated that "aquaculture wastewater alternatives appear to be economically attractive regardless of the market for products if water quality goals are met." Henderson (1978) stocked bighead carp in an existing lagoon treatment system in Arkansas in 1975-1976 to evaluate the effect of the fishes on water quality and the potential for using this nutrient source for fish production. In a follow-up study, Henderson (1979) reported results from a project funded by the USEPA that involved stocking six treatment lagoons of the Benton Services Center treatment plant in Benton, Arkansas. In a later paper, Freeze and Henderson (1982) refer to four stocking sites in Arkansas (specific locations not identified) in addition to the location of state and private hatcheries with bighead carp. With few regulations in place to restrict the sale or possession of bighead carp and with culture information and technical support supplied by the USFWS, fish farmers in Alabama, Arkansas, Mississippi, Missouri, and Oklahoma acquired fish from research facilities and imports, propagated bighead carp as food fish, and began marketing them to ethnic live fish markets. After concerns about introductions into open waters were raised, regulations were mandated to restrict stocking of the species in Arkansas waters, and the control of accidental introductions was investigated (Freeze and Henderson 1982).

Bighead carp first began to appear in open public waters (e.g., the Ohio and Mississippi rivers) in the early 1980's (Freeze and Henderson 1982; Carter 1983), with the first documented evidence of natural reproduction in the Missouri River in 1989 (Pflieger 1997; Kolar et al. 2005). Since their introduction, nearly every state in the Mississippi River Basin and several states outside the basin, have reported bighead carp in their waters. The reproducing populations currently in the Mississippi River Basin could be the result of escape from one or more sources, including: research, state agency, university, and private aquaculture facilities, and illegal introductions (Dill and Cordone 1997; Pigg et al. 1997).

### 2.1.3. Present Distribution and Abundance in the United States

Bighead carp have now been recorded from within or along the borders of at least 23 states (Figure 2.1.2) and are self-sustaining within the Mississippi, Missouri, Ohio, and Tennessee river basins (Kolar et al. 2005; Nico and Fuller 2005a; Schofield et al. 2005). Live bighead carp have been imported to several states outside of the Mississippi River Basin. In October 1999 a fish kill was reported in shallow backwaters on the Upper Mississippi River National Wildlife Refuge near St. Louis that consisted of 97% Asian carps (mostly bighead and silver carps). Among fishes killed, only four native species were found and these were represented by one individual each (personal communication, Chuck Surprenant, USFWS). Adult bigheads have also been reported to concentrate in large numbers below dams on many Midwestern rivers (Iowa to Indiana; MICRA 1999) and juveniles are known to invade small tributaries, particularly areas below spillways (Kolar et al. 2005). Five bighead carp have been collected in western Lake Erie between 1995 and 2003 (Mandrak and Cudmore 2004; Nico and Fuller 2005a).

It is difficult to describe accurately the potential distribution of bighead carp in the United States; however most of the United States lies within the preferred latitudes of bighead carp (Figure 2.1.3). Based on an examination of the present distribution of established and introduced populations around the world, Kolar et al. (2005) conclude that bighead carp have the potential to become established in much of the continental United States. Life history traits of bighead

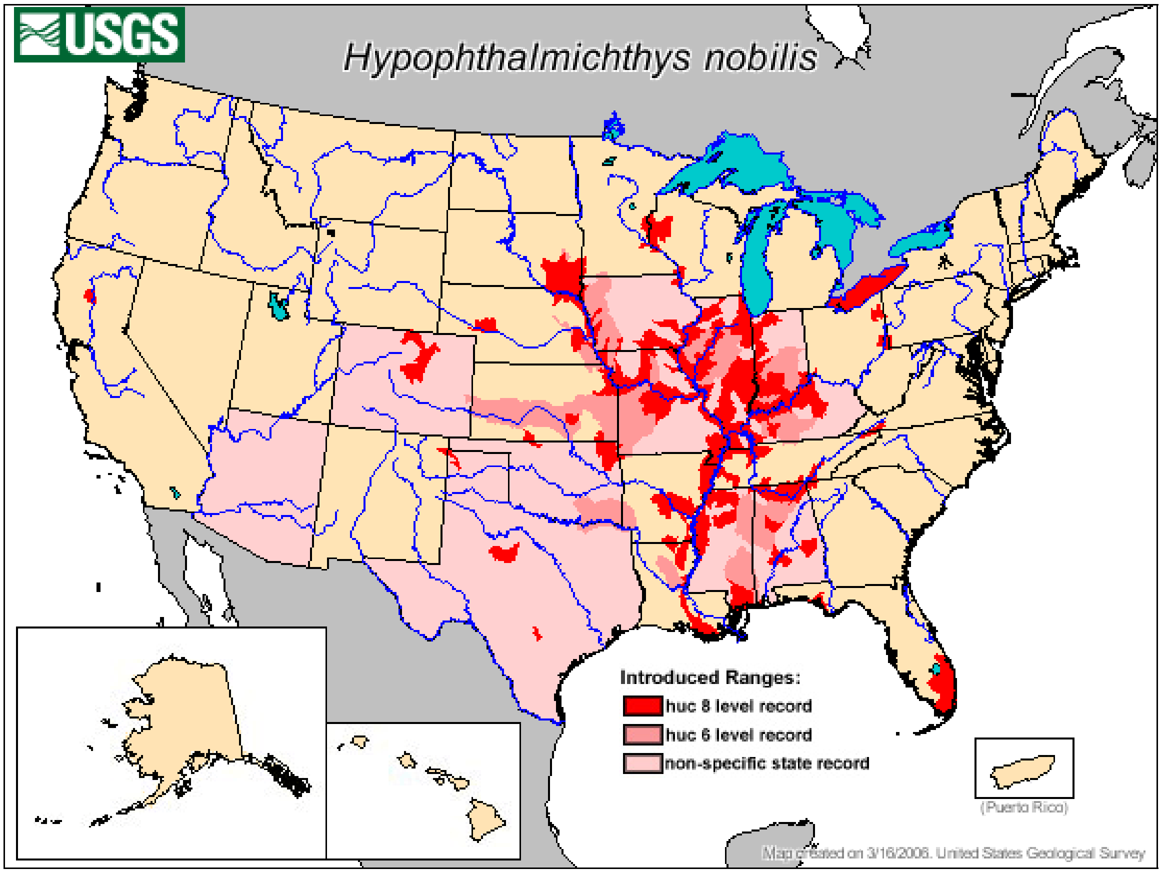


**Figure 2.1.2.** Distribution of bighead carp in the United States as reported in the Nonindigenous Aquatic Species database at the U.S. Geological Survey (USGS). Map reproduced from http://nas.er.usgs.gov/.

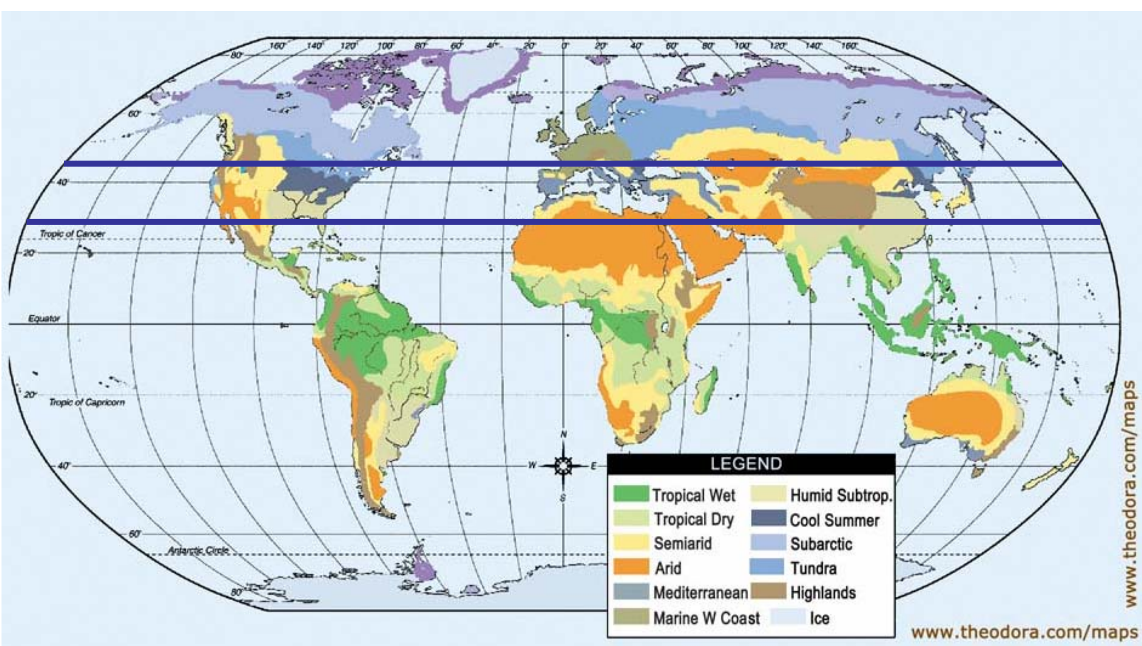


**Figure 2.1.3.** The latitudinal range of bighead carp projected across North America. The native range of bighead carp in eastern Asia extends from approximately 24° N to 43° N; other reports from 21° N to 47° N include introduced populations (Kolar et al. 2005). Map modified from www.theodora.com/maps.

carp suggest they are well adapted to large river systems such as those of the central United States. Limiting factors to range expansions of reproducing populations are most likely access to rivers with moderate to swift current of a length at least 100 km to fulfill spawning requirements, fairly high ionic concentrations for successful egg incubation, and successful recruitment of larvae and juveniles (Kolar et al. 2005).

## 2.1.4. Present Uses within the United States

Some researchers have reported that bighead carp, especially in combination with silver carp, may improve the quality of pond water by continually removing plankton, especially blue-green algae, thereby stabilizing plankton and lessening the probability of die-offs in production ponds (Kolar et al. 2005; Schofield et al. 2005). Studies have yielded conflicting results (Kolar et al. 2005) and Stickney (1996) concluded that more studies would be needed to confirm that bighead carp improve water quality in culture ponds. Stone et al. (2000) stated that changes in the plankton community brought about by bighead carp do not necessarily result in improved water quality or reduced off-flavor in water. In addition to water quality control, bighead carp are used in polyculture with channel catfish and other species in the United States (Kolar et al. 2005) and sold for human consumption at the end of the production cycle, providing supplemental income for catfish producers. The greatest efficiencies were reportedly achieved when catfish and bighead carp were grown separately with nutrient rich water from catfish ponds used as a source of feed for bighead carp (Griffin 1993). This can be an important source of revenue for fish farmers during times of low catfish prices (Stone et al. 2000; DFO 2005).

Bighead carp are cultured for human consumption, both with other species (primarily channel catfish) and sometimes by themselves (Stone et al. 2000). Most live bighead carp produced in the United States are sold from small street markets in major North American cities primarily to consumers (Figure 2.1.4; Stone et al. 2000). “The typical consumer will buy only enough fish for the current day’s meal and will pay top dollar only for live fish” (Stone et al. 2000). In states where consumers can purchase live bighead, the price per pound is relatively higher than for dead bighead (Stone et al. 2000), indicating a distinct consumer preference for the live product. Specialized live haulers transport live fish from fish farms to wholesalers who warehouse the fish and distribute live bighead carp to individual fish markets by smaller trucks (Figure 2.1.5; Stone et al. 2000). Marketing as a live product for ethnic markets in Canada began in 1981 (DFO 2005).


**Figure 2.1.4.** Fish market in New York City. Photo courtesy of David Heikes, University of Arkansas at Pine Bluff.


**Figure 2.1.5.** Delivery of live bighead carp from a wholesaler to a fish market in New York City. Photo courtesy of David Heikes, University of Arkansas at Pine Bluff.

Many governments restrict or prohibit the possession and/or sales of live Asian carps. Ontario amended its provincial Fish & Wildlife Conservation Act to restrict the purchase and sale of live bighead, black, grass and silver carps effective May 2004 (personal communication, Beth Brownson, Ontario Ministry of Natural Resources). Ontario also amended its Fisheries Regulations to restrict live possession of Asian carps effective August 31, 2005 (Canada Gazette 2005). Illinois put new Administrative Rules into effect May 1, 2005, listing bighead, black, and silver carps as Injurious Species, thereby prohibiting the live sales of these fishes within the state (Illinois Administrative Code, Title 17, Chapter 1, Part 805). New York State passed emergency regulations prohibiting import and live sales of bighead, black, and silver carps with the exception that live bighead carp may be sold in New York City, however the fish must be killed by the seller before the purchaser takes possession (New York Conservation Rules and Regulations, Title 6, Chapter 1, Part 180). The State of California prohibits the sale of live bighead carp requiring out-of-state live haulers to kill bighead carp prior to entering the state (personal communication, Bob Hulbrock, California Department of Game and Fish). In the absence of live bighead carp, consumers in California have accepted “freshly dead” products.

Bighead carp have also been used experimentally in the United States to manage water quality in sewage treatment lagoons, manure lagoons, and reservoirs. Henderson (1983) recommended the use of bighead and silver carps to reduce municipal sewage treatment plant operational costs and treatment pond size. Early research in this capacity indicated that facility design greatly determined the overall effect of bighead carp on water quality. Due to their feeding preferences, bighead carp are more effective at feeding on zooplankton than on algae (Kolar et al. 2005).

Commercial enterprises are attempting to develop products and establish markets for wild harvested bighead carp. Commercial harvest of bighead carp is increasing in parts of the Mississippi River Basin. Bighead carp had the highest biomass (3,653 kg, 39%) of fish caught commercially from the Missouri River in Iowa during 2003 (Iowa Department of Natural Resources 2003). The combined annual commercial harvest of bighead and silver carps from the Mississippi and Illinois rivers within Illinois increased from less than 600 kg per year between 1988 and 1992 to over 50,000 kg per year since 1997 (Chick and Pegg 2001). The reported combined commercial harvest of these fishes in 2003 was nearly 60,000 kg from the Mississippi River alone and exceeded 338,000 kg in the Illinois River (Maher 2005).

### 2.1.5. Potential Adverse Effects

Although direct species interactions are not understood fully and competition is difficult to document in large and dynamic river systems (Kolar et al. 2005), the potential of increasing populations of bighead carp to affect native species at all life stages is a concern. Bighead carp are believed to affect many native species adversely because they feed on plankton, the primary food source for mussels, larval fish, and several adult fishes (Laird and Page 1996; Fuller et al. 1999). Sampson (2005) found dietary overlap between bighead carp with gizzard shad and bigmouth buffalo in the Illinois and Mississippi rivers. Schrank et al. (2003) demonstrated dietary overlap between age-0 bighead carp and age-0 paddlefish in mesocosms. Bighead carp have the potential to influence large crustacean zooplankton negatively and to alter food web interactions, thereby potentially affecting other native aquatic organisms (Kohler et al. 2005; Sampson 2005). Field studies to investigate a decline in planktivorous species in areas with abundant bighead carp populations are lacking.

The spread of bighead carp may be adversely affecting the existing commercial fishery in parts of the Mississippi River Basin (Maher 2005). There is not yet a large market for bighead carp in the United States, but in some locations this species has become a substantial portion of the commercial catch (Iowa Department of Natural Resources 2003; Maher 2005; personal communication, Vince Travnichek, Missouri Department of Conservation). Commercial fishers on the Illinois River reported a 124% increase in the harvest of bighead and silver carps (reported together) and a 35% decrease in buffalo harvest during 2002. Unless economically viable markets develop, the establishment of large self-sustaining populations of bighead carp in the United States may compromise commercial fishing.

Feral bighead carp have been reported from rivers of the United States since the 1980's (Freeze and Henderson 1982; Carter 1983) and are no longer a risk of introducing or spreading nonnative pathogens within their current range. However, additional importation of bighead carp into the United States could introduce nonnative pathogens with unknown potential consequences. Scientists have found the Asian tapeworm (*Bothriocephalus acheilognathi*) in bighead carp stocks in China and the former USSR (Kolar et al. 2005).

A recently completed environmental risk assessment, using methods described by the Risk Assessment and Management Committee (1996), concluded that the overall organism risk potential associated with bighead carp is *high* (Kolar et al. 2005). The organism risk potential is based on the probability of bighead carp becoming established and the consequences of bighead carp establishment. The finding of *high organism risk potential* indicates that bighead carp are an organism of major concern and present an unacceptable level of risk. The probability of bighead carp establishment if released (*high*) was determined using the following factors: probability of being within the pathway, probability of the surviving transit, probability of successfully colonizing and maintaining a population where introduced, and probability of spread beyond the colonized area. The consequence of bighead carp establishment (*medium to high*) was determined using the following factors: estimation of economic effect if established, estimation of environmental effect if established, and estimation of effect from social and/or political influences.

## 2.2. BLACK CARP

### 2.2.1. Biology

The black carp (Figure 2.2.1) is large, elongated, laterally compressed and can exceed 1.8 m and 70 kg (Nico et al. 2005). It has a pointed head with a flattened anterior portion and a small toothless mouth (Lin 1991). The body of the black carp is covered with large cycloid scales; coloration of the body varies from brown to black and grading to a bluish-grey or nearly white belly. The fins are darker than the body and most often described as black or brownish-black with lighter hues at the base (Lin 1991; Nico et al. 2005).

**Figure 2.2.1.** Black carp. Photo courtesy of James Candrl, USGS.

Black carp are native to the Pacific drainages of eastern Asia between 22 and 51°N latitudes. Its range extends from the Pearl River Basin in China north to the Amur River and its major tributaries of China and far eastern Russia, including possibly the Red River of northern Viet Nam (Frimodt 1995; Nico et al. 2005). Throughout its native range the black carp inhabits lowland lakes and rivers, mostly at altitudes less than 200 meters above sea level (Li and Fang 1990). The climate of this range varies from subtropical to cold (FAO 1983; Nico et al. 2005).

Black carp have been reported to tolerate dissolved oxygen concentrations as low as 2 ppm. Optimal feeding temperatures for black carp range from 25-30°C; feeding ceases at temperatures < 3°C. Temperatures less than 0.5°C or above 40°C are lethal (Lin 1991).

Recently-hatched black carp fry feed primarily on zooplankton. At 26+ days after hatching (3.1-33 cm), the pharyngeal teeth have fully formed and the fish begin feeding on a larger variety of benthos, insect larvae, and organic detritus (Liu et al. 1990; Lin 1991). Adult black carp feed primarily on mollusks, using their molar like pharyngeal teeth to crush the shells. The species of mollusks consumed varies with geography, fish size, and mouth gape, but usually include gastropods and bivalves (Nico et al. 2005).

Black carp mature from 6-11 years, depending on latitude, diet, and habitat. Males typically mature a year earlier than females. Females average 1 m and 15 kg at maturity while males average 88 cm and 10 kg (Lin 1991; Nico and Williams 1996). Spawning occurs in rivers with water velocities of 0.8-1.8 m/s and water temperatures of 17-30°C (Nico et al. 2005). Increased water flow and temperatures trigger an upstream spawning migration in spring and early summer (Nico et al. 2005). Lin (1991) reported fecundity of females weighing 13.3 kg and 34 kg to be 74.6 and 99 eggs per gram of body weight (about 1.3-3.4 million eggs), respectively.

Black carp eggs are non-adhesive, semi-buoyant, and drift with water currents. Eggs range in size from 4-7 mm diameter and hatch 24 to 35 hours post fertilization, depending on water temperature (Nico et al. 2005). The eggs and larvae are carried into floodplain lakes, smaller streams, and channels with little or no current. These areas serve as nursery areas for larval and juvenile fish. If the drift of eggs and larvae occurs during falling river levels, then the larvae migrate actively to their feeding areas after absorbing the yolk sac (Nico et al. 2005).

### 2.2.2. Introduction to the United States

Black carp were imported into the United States unintentionally in a shipment of grass carp in 1973 (Nico et al. 2005). The initial specimens were trusted into the possession of the Arkansas Game and Fish Commission for evaluation, were never successfully spawned, and were eventually destroyed (personal communication, Mike Freeze, Keo Fish Farm). Black carp were imported intentionally into the United States on several occasions in the 1980's by private fish farmers to control snails in aquaculture ponds and as a potential food fish (Nico et al. 2005). By the early 1990's four private fish farms were producing triploid black carp for use as biological control agents. However, controversy over the black carp has restricted its use in research and management. The presence of some black carp in natural waters indicates that they have escaped from research facilities or private aquaculture facilities.

### 2.2.3. Present Distribution and Abundance in the United States

Agencies, research institutes, or individuals in 11 states have possessed live black carp, received shipments of live black carp, or both, at one time or another. These include Arkansas, Florida, Illinois, Iowa, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, Texas, and Wisconsin (Nico et al. 2005). It has been reported that thirty or more black carp escaped into the Osage River (a tributary to the Missouri River) when high water flooded hatchery ponds at an aquaculture facility in Missouri during April 1994 (Nico et al. 2005; Nico and Fuller 2005b), however the owner of the fish farm states that no black carp have escaped from ponds on his facility (personal communication, Jim Kahrs, Osage Catfisheries, Inc.). To date, six black carp have been collected by commercial fishers from the Mississippi River Basin and their identities verified by biologists (Figure 2.2.2; Nico et al. 2005; Nico and Fuller 2005b). The first verified capture of a black carp in open waters occurred in 2003 in Horseshoe Lake (Alexander County, Illinois), an isolated backwater lake of the Mississippi River. Blood from the fish was examined using a Coulter Counter and was determined to likely be triploid. It is believed that this fish may have entered Horseshoe Lake via the Cache River Drainage, a tributary of the Ohio River. Two black carp were collected in the lower Red River in Louisiana in 2004. Both fish were tested and were likely diploid. A fourth black carp was collected in June 2004 in the Mississippi River near Lock and Dam 24. A fifth black carp was collected in August 2004 from the Atchafalaya River at Simmesport, Louisiana. This fish was also tested and was likely diploid. The sixth verified specimen was collected from the White River in Arkansas in April 2005 (Nico et al. 2005). There are additional unverified reports of repeated captures of adult black carp in the Mississippi River and its tributaries over the past 13 years (Nico et al. 2005). There have been no collections of eggs and larvae or observations of spawning. Although there has been no documented natural reproduction, the continued captures of adult black carp have increased concerns that feral black carp may be reproducing and may establish self-sustaining populations (Nico et al. 2005).

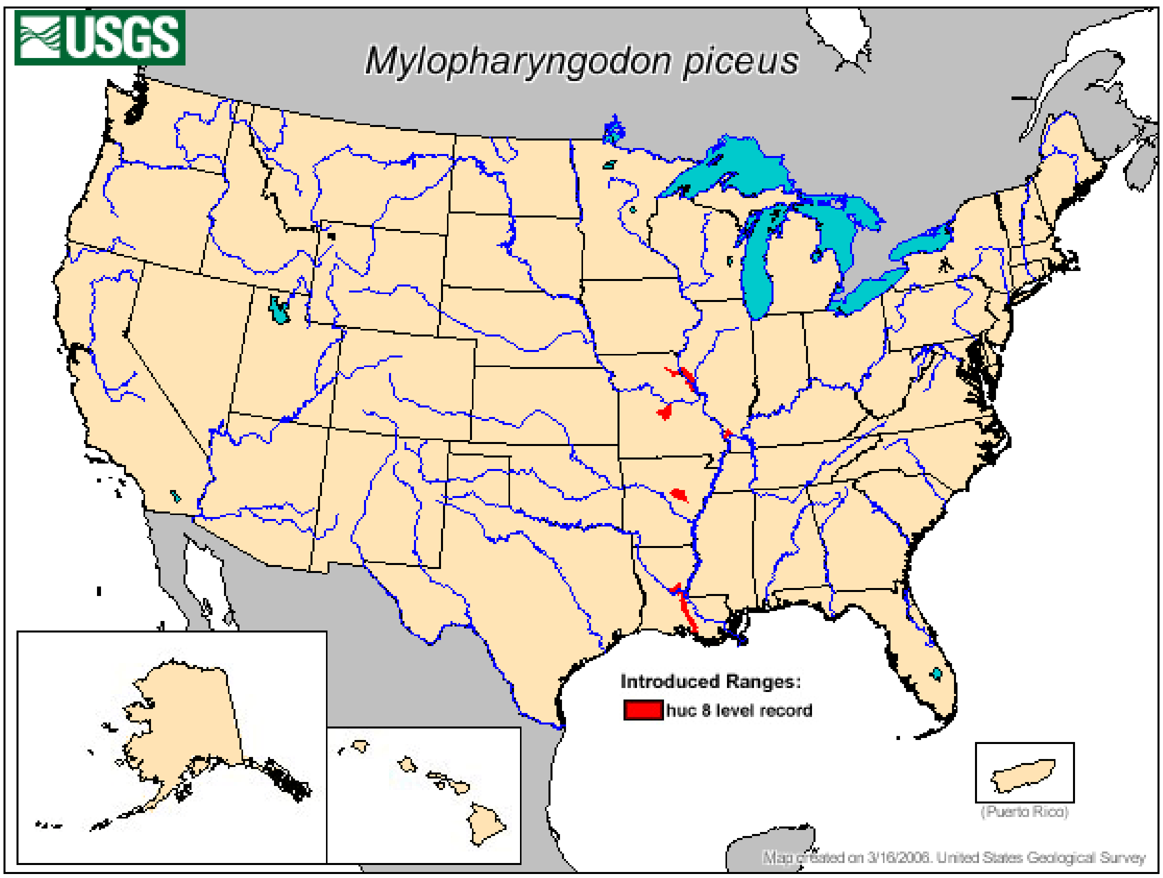


**Figure 2.2.2.** Distribution of black carp in the United States as reported in the Nonindigenous Aquatic Species database at the U.S. Geological Survey (USGS). Map reproduced from http://nas.er.usgs.gov/.

It is difficult to predict the potential distribution of black carp in the United States; however most of the United States lies within the preferred latitudes of black carp (Figure 2.2.3) and there are an abundance of large rivers well suited for black carp. There have been no collections of eggs and larvae or observations of spawning (Nico et al. 2005). Although there has been no documented natural reproduction, the continued capture of adult black carp has increased concerns that feral black carp are reproducing and may establish self-sustaining populations

(Nico et al. 2005). Introduced populations of black carp in other countries, such as Japan and parts of the former Soviet Union, have become established and are reproducing naturally (Nico et al. 2005).

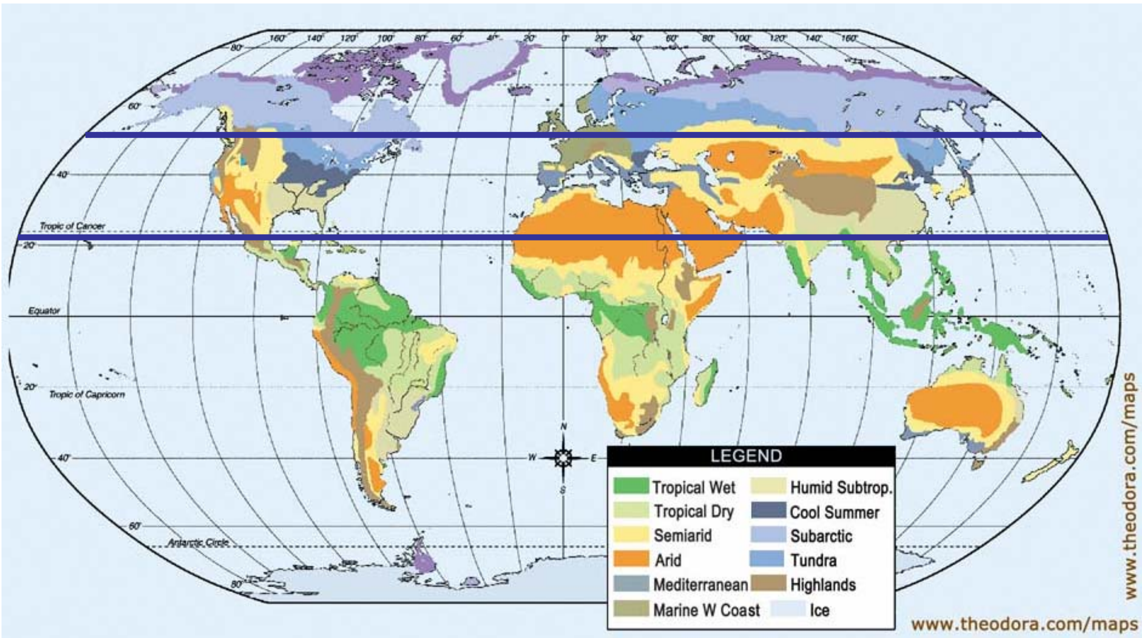


**Figure 2.2.3.** The latitudinal range of black carp projected across North America. The native range of black carp in eastern Asia extends from approximately 22° N to 51° N (Nico et al. 2005). Map modified from www.theodora.com/maps.

## 2.2.4. Present Uses within the United States

In their native China, black carp are an important food fish, with culture of black carp dating back at least 1000 years (Nico et al. 2005). Black carp are considered one of the most desirable food fish in China and fish farmers in the United States anticipated that sales of the fish would be high in ethnic markets. However, to date there is neither demand for black carp in fish markets in the United States nor any commercial production of this fish for the live food market.

Currently black carp are used on aquaculture facilities as biological control agents for snails, which serve as intermediate hosts for several fish parasites that can kill juvenile fish and render fish flesh unmarketable (see Recommendation 3.1.15.10).

There was some interest in black carp as a potential control for zebra mussels. Black carp have been reported to consume zebra mussels, but it is unlikely that black carp are able to break apart clumps or rafts of zebra mussels (Nico et al. 2005). It is also not known whether black carp will select zebra mussels preferentially over native mollusks. Current knowledge of the species suggests that black carp would not be effective in controlling zebra mussel populations (Nico et al. 2005).

## 2.2.5. Potential Adverse Effects

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

2005). Mollusk populations have been reduced greatly by poor water quality, pollution, habitat degradation, commercial harvest, and exotic species introductions [e.g., Asiatic clams (*Corbicula fluminea*) and zebra mussels] (Johnson and Butler 1999). Black carp could add substantially to the problem (Nico et al. 2005). The effects of these fish are likely to be proportional to their abundance in the wild. Introduced individuals or a reproducing population of black carp in open waters of the United States could pose a serious threat to many of the remaining populations of threatened and endangered mollusks (Nico et al. 2005), however there is a vast difference between the long-term effects of introduced individuals and a reproducing population of these fish. Black carp could consume many imperiled native mussels. Nico et al. (2005) concluded that all size classes of 12 (85%) of the 14 federally endangered unionid species in Midwestern rivers are within the gape limits of a 2 m long black carp. Because there are no known native molluskivores with a similar combination of size, morphology, and diet, the black carp could potentially fill a niche in North American rivers currently unoccupied and consequently alter food webs substantially (Nico et al. 2005).

Although direct species interactions are not fully understood, established populations of black carp could compete with native fishes that feed on small mollusks. Freshwater drum (*Aplodinotus grunniens*), redear sunfish (*Lepomis microlophus*), several ictalurid catfishes, and several redhorse species (*Moxostoma* spp.) may be affected (Nico et al. 2005). In addition, larval and juvenile black carp consume plankton, insect larvae, and detritus (Lin 1991) and potentially could compete for food with native larval and juvenile fishes if these resources are limited.

Additional importation of black carp into the United States could introduce nonnative pathogens with unknown potential consequences. Nico and Williams (1996) concluded that until black carp are evaluated as a pathway for disease, no additional stocks of black carp should be imported without additional precautions. Scientists have found the Asian tapeworm in stocks of black carp in the former USSR (Nico et al. 2005).

A recently completed environmental risk assessment, using methods described by the Risk Assessment and Management Committee (1996), concluded that the overall organism risk potential associated with black carp is *high* (Nico et al. 2005). The organism risk potential is based on the probability of black carp becoming established and the consequences of black carp establishment. The finding of *high organism risk potential* indicates that black carp are an organism of major concern that compels mitigation. The probability of black carp establishment if released (*high*) was determined using the following factors: probability of being within the pathway, probability of surviving in transit, probability of successfully colonizing and maintaining a population where introduced, and probability of spread beyond the colonized area. The consequence of black carp establishment (*high*) was determined using the following factors: estimation of economic effect if established, estimation of environmental effect if established, and estimation of effect from social and/or political influences.

# 2.3. GRASS CARP

## 2.3.1. Biology

The grass carp (Figure 2.3.1) is large, elongated, laterally compressed, and can grow to lengths of 1.6 m and weights of 37 kg (Pflieger 1997; Bowman 1998). The head is slightly flattened, with moderately small eyes centered on the side

**Figure 2.3.1.** Grass carp. Picture courtesy of Duane Chapman, USGS.

of the head. The body is covered with large cycloid scales. Coloration of the body varies from blackish or olive-brown, grading to brassy or silvery-white on the sides and belly. Scale pockets on the back and sides are outlined by dusky pigment, giving a crosshatched effect (Pflieger 1997).

Grass carp are native to the large rivers of eastern Asia. Its native range extends from southern Russia to northern Vietnam and from coastal waters inland. The grass carp is a sub-tropical to temperate species found between 25-65°N latitudes (Lee et. al. 1980; Shireman and Smith 1983; Froese and Pauly 2001). The grass carp is most commonly reported to inhabit lower and middle reaches of rivers. Grass carp prefer large, slow flowing water bodies with available vegetation. Grass carp can tolerate water temperatures between 0-38°C, but prefer temperatures of 10-26°C. The species can withstand dissolved oxygen concentrations as low as 0.5 ppm and salinities to 10 ppt (Froese and Pauly 2001)

Grass carp possess comb-like pharyngeal teeth that are used to grind vegetation. Adult grass carp prefer a diet of submerged plants with soft leaves (Bain et al. 1990; Pine and Anderson 1991) and will consume filamentous algae and firmer macrophytes [e.g., Eurasian milfoil (*Myriophyllum spicatum*)] when preferred forage has been exhausted (Opuszynski and Shireman 1995). In the absence of aquatic vegetation, grass carp have been reported to consume organic detritus, insects, small fish, earthworms, and other invertebrates (Laird and Page 1996; Froese and Pauly 2001). Grass carp can consume up to 40% of their body weight per day in aquatic vegetation (Laird and Page 1996).

Grass carp grow rapidly before the onset of maturity, reaching 1 kg by age one and growing 2-3 kg per year in temperate climates and 4.5 kg/year in tropical climates (Shireman and Smith 1983). Age at maturity ranges from 2-10 years (50-86 cm) and is largely a function of water temperature and diet (Cudmore and Mandrak 2004). Males generally mature one year earlier than females. Spawning activity is associated with high spring flows, and spawning areas have high water velocity, turbid water, and a temperature in the range of 15-30°C (Cudmore and Mandrak 2004). Grass carp spawn primarily in the main river channel in the upper part of the water column over rapids or sand bars during times of turbulent water currents ranging from 0.6 to 1.5 m/s (Shireman and Smith 1983). Fecundity is directly proportional to length, weight, and age, averaging 500,000 eggs for a 5 kg female (Shireman and Smith 1983; Chilton and Muoneke 1992).

Grass carp eggs are non-adhesive and semi-buoyant, requiring flowing water for incubation (Cudmore and Mandrak 2004). Eggs can become dispersed widely from the spawning site and have reportedly traveled downstream as far as 180 km (Fedorenko and Fraiser 1978). Successful reproduction requires long stretches of warm, flowing water for egg incubation and suitable backwater habitats for larval development (Verigin et al. 1978). Floodplains associated with rising water levels provide nursery habitat areas for larvae and juvenile forms. Larval grass carp initially feed on rotifers and protozoans, switching to larger cladocerans and insect larvae at 11-15 days post-hatch (Fedorenko and Fraser 1978; Opuszynski and Shireman 1995). Three weeks post-hatch, grass carp begin feeding on filamentous algae and macrophytes. By the age of 1 to 1.5 months grass carp feed exclusively on macrophytes (Opuszynski and Shireman 1995).

### 2.3.2. Introduction to the United States

Grass carp were brought into the United States in 1963 through a joint action of the United Nations Food and Agriculture Organization, the USFWS, and Auburn University to evaluate their use as a biological control for aquatic vegetation (Avault 1965; Stevenson 1964; Pflieger 1978; Leslie et al. 1996; Mitchell and Kelly 2006). The original fish were housed at the USFWS Fish Farming Experiment Station in Stuttgart, Arkansas (Figure 2.3.2) and Auburn University, Alabama (Avault 1965; Stevenson 1964; Pflieger 1978; Leslie et al. 1996; Mitchell and Kelly 2006). These stocks reached sexual maturity in 1966 and were spawned at both facilities (Mitchell and Kelly 2006). Some of the offspring produced by the USFWS in Stuttgart, Arkansas are thought to have escaped in 1966 and newly hatched grass carp fry were observed passing through screens on rearing troughs in 1970 (Mitchell and Kelly 2006).

Figure 5:--A shipment of grass carp from Malaysia arrived at the station, November 16.

**Figure 2.3.2.** A picture of the first grass carp shipment to the United States arriving at the U.S. Fish and Wildlife Service laboratory at Stuttgart, Arkansas, on November 16, 1963 (Photo copied from Stevenson 1964).

The Arkansas Game and Fish Commission stocked Lake Greenlee, a topographically isolated lake near Brinkley, Arkansas, in 1969 and 1970 (Leslie et al. 1996; Mitchell and Kelly 2006). In 1971, the Arkansas Game and Fish Commission produced 1 million grass carp fry and stocked the first reservoir open to a stream system, Lake Conway, and began providing out-of-state researchers with fish (Guillory and Gasaway 1978). By 1972 grass carp had been shipped to at least 16 states (Guillory and Gasaway 1978) and the Director of the USFWS Fish Farming Experiment Station (K.E. Sneed) reported that grass carp had been introduced into 40 states (Pflieger 1978). By 1975, the Arkansas Game and Fish Commission had stocked 380,000 grass carp in more than 100 lakes throughout the state (Guillory and Gasaway 1978; Pflieger 1978).

Feral grass carp were collected in 1970 in the White River, Arkansas and in the Illinois portion of the Mississippi River in 1971 (Mitchell and Kelly 2006). Age determination indicated the fish were from the 1966 year class and most likely had escaped from the USFWS facility in Stuttgart, Arkansas (Mitchell and Kelly 2006). By 1974 feral grass carp from the 1971 year class began to appear with great frequency in the Mississippi River (Pflieger 1978). Other free ranging or escaped grass carp appeared in rivers of Alabama, Florida, Georgia, and Mississippi (Mitchell and Kelly 2006).

Realizing the effectiveness of grass carp for controlling nuisance aquatic vegetation, private fish hatcheries began importing grass carp in 1972 (Mitchell and Kelly 2006). By 1973 grass carp, marketed as white amur, were being sold to private pond owners via trade magazines for aquatic vegetation control. Few regulations existed to restrict the distribution of grass carp.

By the late 1970s a growing controversy had developed regarding the grass carp's potential to reproduce in river systems in the United States and many states banned the importation of diploid grass carp (Leslie et al. 1996). Private hatcheries, attempting to create an environmentally safe grass carp, began developing hybrid, sterile, and mono-sex stocks of grass carp (Leslie et al. 1996).

In 1983 a private fish hatchery in Arkansas produced the first triploid grass carp on a commercially viable scale (Malone 1984), pioneered the Coulter Counter for blood testing individual fish to ensure 100% triploid stocks, and initiated USFWS involvement in ploidy inspection and verification (Mitchell and Kelly 2006). In 1985 the USFWS established a triploid grass carp ploidy inspection program that opened the way to ship certified triploid grass carp around the country (Griffin 1991). Triploid grass carp sales have grown to more than 400,000 fish per year with more than 30 states receiving USFWS certified triploid grass carp through 2004 (Mitchell and Kelly 2006). From 2002-2004, more than 1.3 million triploid grass carp were shipped with USFWS certification to more than 20 states for aquatic vegetation control (Mitchell and Kelly 2006).

## 2.3.3. Present Distribution and Abundance in the United States

Grass carp have been widely distributed throughout the United States. Grass carp are currently reported in every state except Alaska, Rhode Island, Maine, Vermont, and Montana (Figure 2.3.3) primarily because they are deliberately stocked by various natural resources management agencies and private pond owners as a cost-effective biological control for certain nuisance aquatic plants, and due to their use in research projects, escape from aquaculture facilities, and dispersal from introduced sites (Fuller et al. 1999). Grass carp are considered established in Arkansas, Kentucky, Illinois, Louisiana, Missouri, Mississippi, Oklahoma, Tennessee, and Texas (Courtenay 1993; Nico et al. 2006; personal communication, Jeff Boxrucker, Oklahoma Department of Wildlife Conservation). Self-sustaining populations of grass carp are established within or along the borders of at least nine states, reproducing in rivers such as the Mississippi, Missouri, Ohio, and Trinity and some tributaries (Schofield et al. 2005; Nico et al. 2006). Grass carp have also been reported in Lakes Michigan, Erie, Huron, and Ontario (Cudmore and Mandrak 2004; USGS 2006).

## 2.3.4. Present Uses within the United States

Diploid (i.e., fertile) and triploid (i.e., sterile) grass carp continue to be used as an effective biological control for vegetation in lakes and ponds (Cassani 1996). Hoyer et al. (2005) concluded “it is clear that if there was some cost-effective and selective method of removing grass carp from a lake system before complete eradication of submersed aquatic vegetation was accomplished then triploid grass carp would be an excellent method of hydrilla control for large and small lakes.” State natural resources management agencies, working with the USFWS, have used triploid grass carp for aquatic vegetation control, particularly in those states with the most severe aquatic vegetation problems. Many state fishery management agencies (34) offer some type of guidance for stocking grass carp, with 23 states specifying a stocking rate and whether triploid or diploid fish are allowed (Dauwalter and Jackson 2005). Grass carp are also used widely for vegetation control by private aquaculture facilities; approximately 42% of catfish production facilities use grass carp for vegetation control (APHIS 2003). A substantial trade in the species exists for use in commercial aquaculture facilities, private ponds and lakes, public ponds and lakes, and municipal irrigation projects. Triploid grass carp sales have grown to more than 400,000 fish per year with more than 30 states receiving USFWS certified triploid grass carp through 2004 (Mitchell and Kelly 2006). Millions of dollars are spent on aquatic vegetation management in the United States annually (Greenfield et al. 2004). While many control measures exist, the use of grass carp is the least expensive, costing $45 to $125 per acre (Greenfield et al. 2004). Markets also exist for farm-raised grass carp in small ethnic fish markets of some large cities in the United States and Canada.

Triploid grass carp can be considered sterile for management purposes (Nico et al. 2005). Triploid female grass carp have greatly reduced ovaries and are functionally sterile (Thorgaard

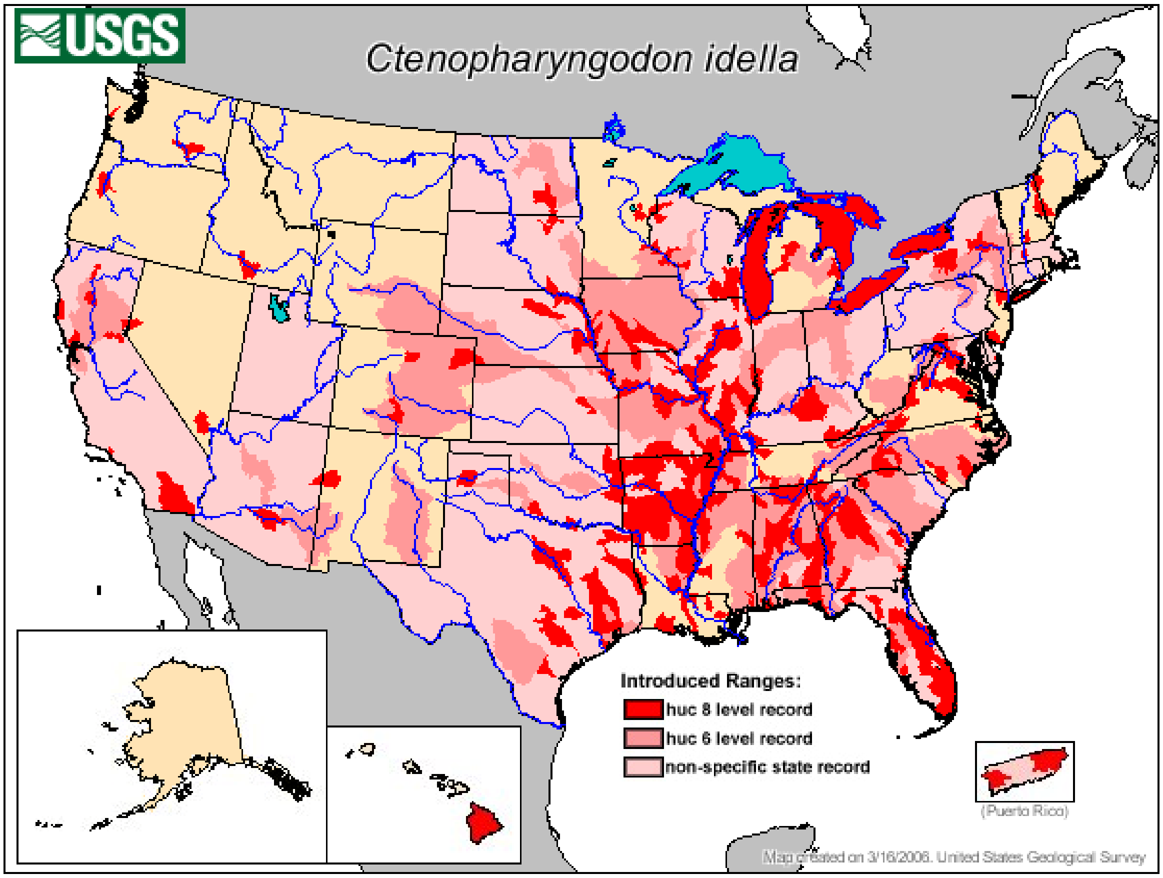


**Figure 2.3.3.** Distribution of grass carp in the United States as reported in the Nonindigenous Aquatic Species database at the U.S. Geological Survey (USGS). Map reproduced from http://nas.er.usgs.gov/.

and Allen 1987; Benfey 1999; Devlin and Nagahama 2002). In contrast, Doroshov (1986) and Mager (1993) determined that triploid male grass carp undergo complete spermatogenesis, however, they produce very low numbers of viable sperm. For grass carp, cytological studies have demonstrated only about 60 viable spermatids for every billion cells, and that even with artificial insemination using normal eggs from diploid females, no viable larvae were produced (Allen et al. 1986; Allen and Wattendorf 1987; Van Eenennaam et al. 1990). The risk of triploid grass carp successfully reproducing is only realized in populations where triploid males can spawn with diploid females, and is very low (Allen et al. 1986; Doroshov 1986; Mager 1993). The Grass Carp Ad Hoc Panel concluded that “triploids proposed for introduction are considered functionally sterile and even when triploids are mated with diploids the offspring do not develop or do not survive” (Chesapeake Bay Program 1994). Nico et al. (2001) indicated that they were not aware of any research documenting reversion among grass carp or other triploid fish. The induction of triploidy is less than 100% effective, requiring all fish to be individually tested for ploidy determination and diploid fish removed. The effectiveness of triploidy is, therefore, dependent upon the quality and integrity of the inspection and certification processes to screen fish prior to shipping or stocking.

Thirty-eight states authorize triploid grass carp stocking for biological control of nuisance aquatic vegetation and ten states allow diploids to be stocked, however twelve states (and the District of Columbia) prohibit the use of grass carp in their waters (Table 2.3.1; Dauwalter and Jackson 2005; personal communication, Jill Popham, USFWS). Twenty-nine states restrict the stocking of grass carp to triploids only and all but Tennessee require triploid grass carp to be certified.

**Table 2.3.1.** Summary of state grass carp importation regulations. Information provided by the USFWS Triploid Grass Carp Inspection and Certification Program.

| State | Diploid Grass Carp | Triploid Grass carp | Grass Carp Banned | Triploid Certification Required[1] |
|---|---|---|---|---|
| Alabama | **Yes** | **Yes** | *No* | *No* |
| Alaska | *No* | *No* | **Yes** | *No* |
| Arizona | *No* | **Yes** | *No* | **Yes** |
| Arkansas | **Yes** | **Yes** | *No* | *No* |
| California | *No* | **Yes** | *No* | **Yes** |
| Colorado | **Yes** [2] | **Yes** | *No* | **Yes** |
| Connecticut | *No* | **Yes** | *No* | **Yes** |
| Delaware | *No* | **Yes** | *No* | **Yes** |
| Florida | *No* | **Yes** | *No* | **Yes** |
| Georgia | *No* | **Yes** | *No* | **Yes** [3] |
| Hawaii | **Yes** | **Yes** | *No* | *No* |
| Idaho | *No* | **Yes** | *No* | **Yes** |
| Illinois | *No* | **Yes** | *No* | **Yes** |
| Indiana | *No* | **Yes** | *No* | **Yes** |
| Iowa | **Yes** | **Yes** | *No* | *No* |
| Kansas | **Yes** | **Yes** | *No* | *No* |
| Kentucky | *No* | **Yes** | *No* | **Yes** |
| Louisiana | *No* | **Yes** | *No* | **Yes** |
| Maine | *No* | *No* | **Yes** | *No* |
| Maryland | *No* | *No* | *No* | *No* |
| Massachusetts | *No* | *No* | **Yes** | *No* |
| Michigan | *No* | *No* | **Yes**[4] | *No* |
| Minnesota | *No* | *No* | **Yes** | *No* |
| Mississippi | **Yes** | **Yes** | *No* | *No* |
| Missouri | **Yes** | **Yes** | *No* | *No* |
| Montana | *No* | *No* | **Yes** | *No* |
| Nebraska | **Yes** | **Yes** | *No* | *No* |
| Nevada | *No* | **Yes** | *No* | **Yes** |
| New Hampshire | *No* | *No* | **Yes** | *No* |
| New Jersey | *No* | **Yes** | *No* | **Yes** |
| New Mexico | *No* | **Yes** | *No* | **Yes** |
| New York | *No* | **Yes** | *No* | **Yes** |
| North Carolina | *No* | **Yes** | *No* | **Yes** |
| North Dakota | *No* | *No* | **Yes** | *No* |
| Ohio | *No* | **Yes** | *No* | **Yes** |

[1] States marked with a "Yes" require triploid certification. Some of these states require USFWS certification while others accept USFWS certification or an alternate triploid certification.
[2] Colorado only allows diploids in the eastern half of the state.
[3] Georgia requires USFWS certification for fish shipped from Arkansas and Indiana producers.
[4] Michigan bans grass carp, but allows eggs to be imported for research purposes.

**Table 2.3.1.** Continued.

| State | Diploid Grass Carp | Triploid Grass Carp | Grass Carp Banned | Triploid Certification Required[5] |
|---|---|---|---|---|
| Oklahoma | **Yes** | **Yes** | *No* | *No* |
| Oregon | *No* | **Yes** | *No* | **Yes** |
| Pennsylvania | *No* | **Yes** | *No* | **Yes** |
| Rhode Island | *No* | *No* | **Yes** | *No* |
| South Carolina | *No* | **Yes** | *No* | **Yes** [5] |
| South Dakota | *No* | **Yes** | *No* | **Yes** |
| Tennessee | *No* | **Yes** | *No* | *No* |
| Vermont | *No* | *No* | **Yes** | *No* |
| Virginia | *No* | **Yes** | *No* | **Yes** |
| Washington | *No* | **Yes** | *No* | **Yes** |
| Washington D.C. | *No* | *No* | **Yes** | *No* |
| West Virginia | *No* | **Yes** | *No* | **Yes** |
| Wisconsin | *No* | *No* | **Yes** | *No* |
| Wyoming | *No* | **Yes** | *No* | **Yes** |

[5] States marked with a "Yes" require triploid certification. Some of these states require USFWS certification while others accept USFWS certification or an alternate triploid certification.
[5] South Carolina conducts its own inspection of all triploid grass carp shipments entering the state.

Alabama, Arkansas, Illinois, Iowa, Kansas, Mississippi, Missouri, Nebraska, and Oklahoma allow private fish farmers to possess diploid brood stock for the production of diploid or triploid grass carp. Indiana, Florida, Georgia, and Kentucky allow private fish farmers to possess diploid broodstock for the production of triploid grass carp for sale (all diploid offspring produced must be destroyed upon blood testing). California allows the Imperial Irrigation District to maintain diploid grass carp broodstock for the production of triploids for use in California. Culture of diploid grass carp as food fish is permitted in Alabama, Arkansas, Iowa, Kansas, Mississippi, Missouri, Nebraska, and Oklahoma (personal communication, Robert Glennon, J. M. Malone and Sons Inc.).

In 1996 grass carp represented 8% of the total commercial harvest from the Mississippi and Missouri Rivers (Nico et al. 2006). Grass carp had the fourth highest biomass (1,139 kg, 12%) of fish commercially caught from the Missouri River in Iowa during 2003 (Iowa Department of Natural Resources 2003). Grass carp offer limited opportunities for recreational fishing; however the fish is popular with some fly fisherman. Some states (such as Florida) require the immediate release of grass carp caught in public waters.

## 2.3.5. Potential Adverse Effects

Grass carp are stocked to alter "undesirable" habitats by consuming nuisance aquatic vegetation. However, Hoyer et al. (2005) concluded that there is "little hard evidence that submersed aquatic plant control can be achieved with low density stocking of grass carp while maintaining some submersed aquatic vegetation." Grass carp are long-lived, are often overstocked, and can result in unintended effects in both target and non-target locations (Cassani 1996). High densities of grass carp have the potential to alter habitats significantly and affect native communities adversely through interspecific competition with invertebrates and other fishes; decrease refugia for aquatic organisms; modify preferred fish habitats; increase nutrient enrichment and eutrophication of lakes; disrupt food webs and trophic structure; and spread nonnative parasites and diseases (Nico et al. 2006). Given favorable conditions, diploid grass carp may reproduce and create a self-sustaining population, while the effects of triploid grass carp are limited to the life spans of the individual fish. Grass carp have been reported to consume all available aquatic vegetation in some lakes (Froese and Pauly 2001). Grass carp are also known to consume terrestrial vegetation (Kilgen and Smitherman1971; Terrell and Fox 1974) by digging into banks and uprooting riparian vegetation (personal communication, Duane Chapman, USGS). This method of feeding damages banks and may cause erosion. Grass carp have been associated with increased turbidity and alkalinity and reduced dissolved oxygen as a result of their feeding behavior and removal of macrophytes (Lembi et al. 1978; Mitzner 1978; Leslie et al. 1983). Competition for vegetation has been documented to decrease abundances of snails and cause significant declines in crayfish populations (Fedorenko and Fraiser 1978; Chilton and Muoneke 1992). The removal of macrophytes can directly degrade habitat for those fishes which depend upon aquatic vegetation for all or part of their life cycle, such as northern pike (*Esox lucius*) and largemouth bass (Taylor et al 1984; Chilton and Muoneke 1992). Although reports describing the effects on overall standing crops of fish in ponds stocked with grass carp are conflicting, the standing crop of bluegill (*Lepomis macrochirus*) was found to be significantly lower in ponds where grass carp were introduced (Forester and Lawrence 1978).

Feral grass carp have been reported from rivers of the United States since 1970 (Mitchell and Kelly 2006) and are no longer a risk of introducing or spreading nonnative pathogens within their current range. However, any additional importation of grass carp into the United States could introduce nonnative pathogens with unknown potential consequences. Grass carp are known to host the Asian tapeworm, a cestode parasite thought to be initially introduced into the United States with imported grass carp (Hoffman and Schubert 1984; McCann et al. 1996; Hoole et al. 2001) or common carp. The parasite has been documented in grass carp on fish farms in the United States (American Fisheries Society 2004). Grass carp are highly migratory, transported across watersheds, and widely stocked; factors that make this fish a concern for the further dispersal of the Asian tapeworm in waters of the United States.

A national risk assessment for grass carp has not been completed and state-level risk assessments may still be needed where grass carp have not been reported or where the species has not become established.

# 2.4. SILVER CARP

## 2.4.1. Biology

The silver carp (Figure 2.4.1) is large, deep-bodied, and can grow to lengths of 1 m and weights of 27 kg. It has a moderately large and broad head encompassing just less than 1/3 of its body size, a toothless upturned lower jaw, and eyes located below the axis of the body (Lin 1991; Pflieger 1997). Coloration of the body is generally silver on the sides with a slate grey head and dorsal surface, and the belly is white (Lin 1991; Pflieger 1997).

**Figure 2.4.1.** Silver carp. Picture courtesy of USFWS, Carterville Fishery Resources Office.

Silver carp are native to several major Pacific drainages in eastern Asia (Fuller et al. 1999) and prefer standing or slow flowing water of impoundments or river backwaters ranging in temperature from 6-28°C. A very active, schooling species (Mukhamedova 1977; Kolar et al. 2005), that are well known for their habit of leaping out of the water when disturbed (Skelton 1993). Adult silver carp in the lower Missouri River usually use low velocity areas behind wing dikes, especially areas greater than 3 m deep, and during the winter, occupied depths between 1-5 m deep (unpublished data, Duane Chapman, USGS). Thousands of individuals have also been observed in some off-channel areas of the Mississippi River (unpublished data, Nate Caswell, USFWS). There are indications that silver carp can live in slightly brackish water (FAO 1972; Kolar et al. 2005).

Silver carp very efficiently strain suspended material from the water with highly specialized gill rakers that are fused into sponge-like porous plates (Robison and Buchanan 1988). They feed primarily on phytoplankton, but also feed on zooplankton, invertebrates, detritus, and bacteria, especially when phytoplankton abundance is low (Burke et al. 1986; Kolar et al. 2005). Silver carp lack a true stomach which requires them to feed almost continuously (Henderson 1976). Female silver carp reach sexual maturity at three to four years of age with a body weight of 7-14 kg, while males can reach maturity in two years with a body weight of 5-13 kg, however, this can change significantly with environmental conditions. Spawning activity is associated with high spring flows, and spawning areas have high water velocity, turbid water, and a temperature in the range of 18-30°C; optimal water temperature for spawning is 22-28°C (Lin 1991). Silver carp produce eggs that are semi-buoyant and require current to prevent the eggs from sinking to the bottom. Floodplains associated with rising water levels provide nursery habitat areas for larvae and juvenile forms (Lin 1991; Froese and Pauly 2001; Kolar et al. 2005). Egg production per females varies with location and body size, ranging from 50,000 to 5,000,000 (Singh 1989; Kamilov and Salikhov 1996; Froese and Pauly 2001).

## 2.4.2. Introduction to the United States

Silver carp were first brought into the United States in 1973 by a private fish farmer in Arkansas (Freeze and Henderson 1982) as a potential biological control agent to improve water quality in municipal sewage treatment lagoons and aquaculture ponds and as a food fish (Froese and Pauly 2001). The initial specimens were trusted into the possession of the Arkansas Game and Fish Commission for evaluation (personal communication, Mike Freeze, Keo Fish Farm). By 1974-1975, silver carp were being evaluated by the Arkansas Game and Fish Commission, Auburn University, and the Illinois Natural History Survey for use in municipal sewage treatment lagoons, commercial fish production ponds, and swine manure lagoons, respectively. Henderson (1983) recommended the use of bighead and silver carps to reduce municipal sewage treatment plant operational costs and treatment pond size. At one time, six federal, state, and private facilities in Arkansas raised silver carp and four municipal sewage lagoons had been stocked with silver carp. The Arkansas Game and Fish Commission stocked 400 adult silver carp into Mallard Lake in 1983 for a phytoplankton control experiment. This same lake was drained and treated with rotenone the next year during planned renovation. Some of these silver carp may have entered the St. Francis River which drains into the Mississippi River (personal communication, Don Brader, Arkansas Game and Fish Commission).

The reproducing populations of silver carp currently in the Mississippi River Basin could be the result of escape from one or more sources, including: research facilities, municipal facilities, universities, state hatcheries, and private fish farms. By 1981, feral silver carp were recorded in seven locations in Arkansas (Robison and Buchanan 1988), including the White, Arkansas, and Mississippi rivers. Since their introduction, silver carp have been reported in nearly every state in the Mississippi River Basin and several states outside the basin. The first reported natural reproduction of silver carp in the United States was from a ditch near Horseshoe Lake, Alexander County, Illinois during 1995 (Pflieger 1997).

## 2.4.3. Present Distribution and Abundance in the United States

Silver carp have now been recorded from within or along the borders of at least 16 states (Figure 2.4.2) and are self-sustaining within the Mississippi, Missouri and Ohio River drainages (Kolar et al. 2005; Schofield et al. 2005). Established populations of reproducing and over-wintering silver carp have been confirmed in 10 states (Nico 2005). The silver carp appears to be adapting very well to the temperate climates of the United States. It continues to colonize in a northward direction and is spreading rapidly throughout the Mississippi River Basin. Large numbers of fish and substantial natural reproduction have been documented in off-channel and backwater habitats (MICRA 1999; unpublished data, Nate Caswell, USFWS).
Live silver carp have been imported to several states outside of the Mississippi River Basin (e.g., Alabama, Florida, North Carolina, and California).

It is difficult to predict the potential distribution of silver carp in the United States; however most of the United States lies within the preferred latitudes of bighead carp (Figure 2.4.3). Based on an examination of the present distribution of established and introduced populations around the world, Kolar et al. (2005) conclude that bighead carp have the potential to become established in much of the continental United States. Life history traits of silver carp suggest they are well adapted to large river systems such as those of the central United States. Limiting factors to range expansions of reproducing populations are most likely access to rivers with moderate to swift current of a length at least 100 km to fulfill spawning requirements, fairly high ionic concentrations for successful egg incubation, and successful recruitment of larvae and juveniles (Kolar et al. 2005).

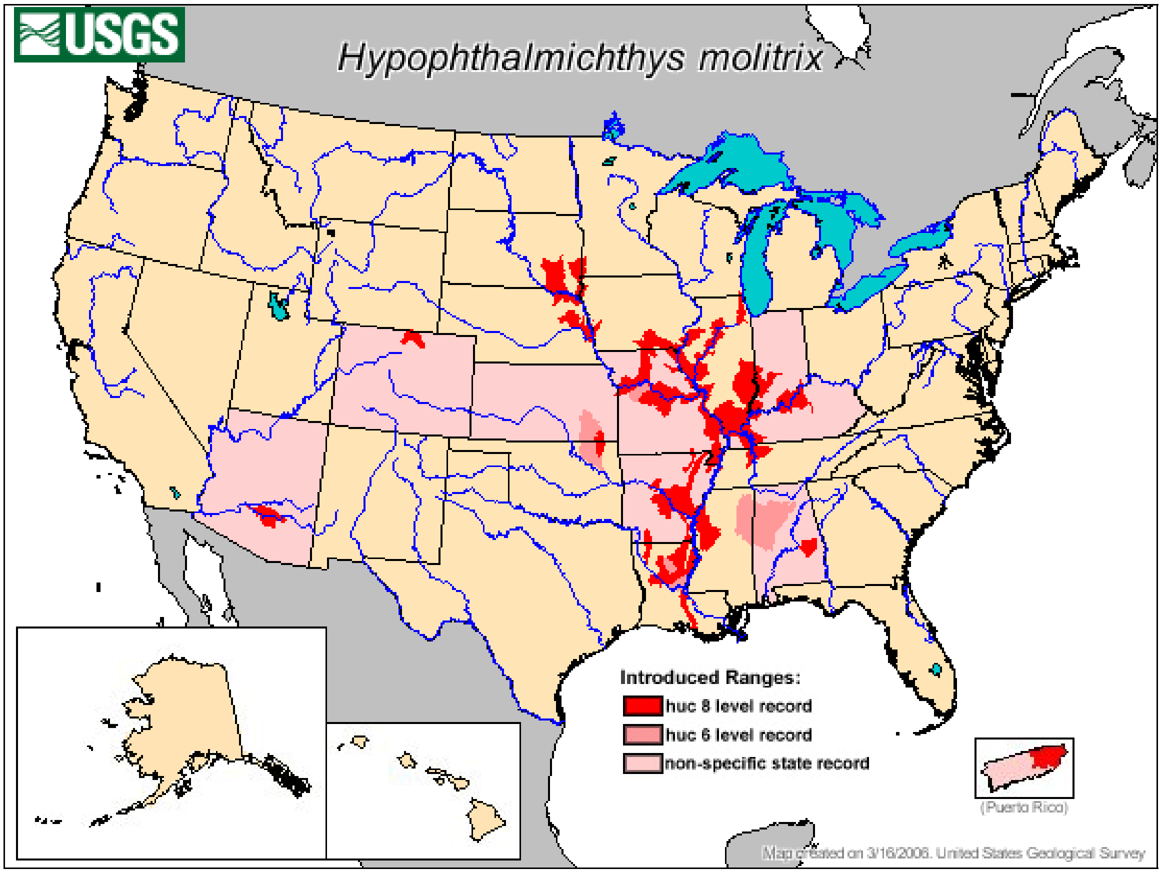


**Figure 2.4.2.** Distribution of silver carp in the United States as reported in the Nonindigenous Aquatic Species database at the U.S. Geological Survey (USGS). Map reproduced from http://nas.er.usgs.gov/.

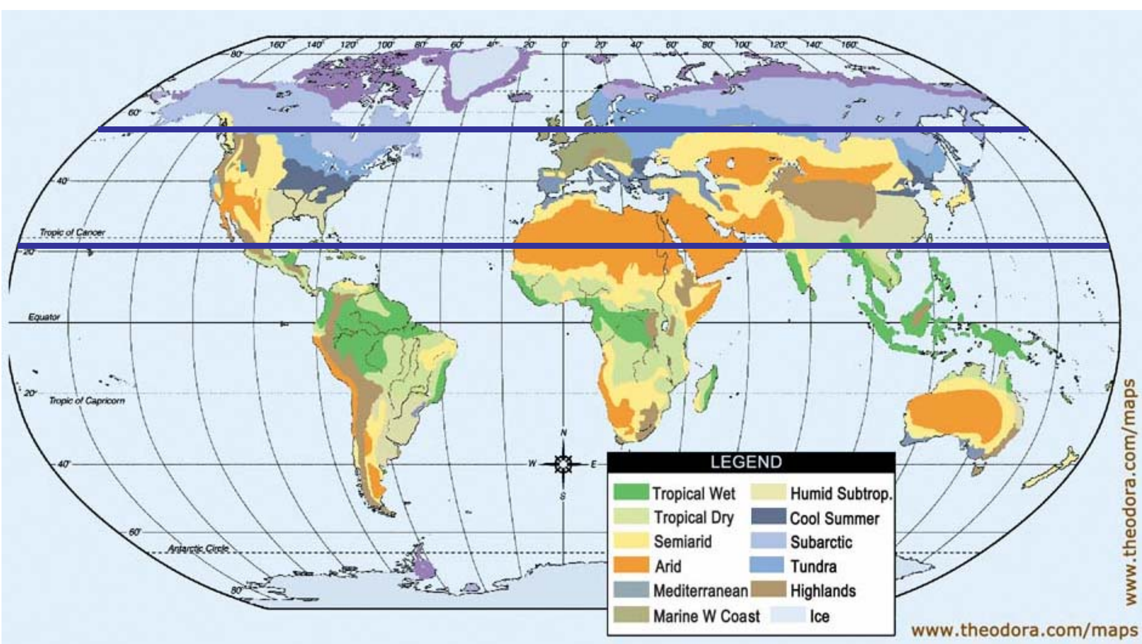


**Figure 2.4.3.** The latitudinal range of silver carp projected across North America. The native range of silver carp in eastern Asia extends from approximately 21° N to 54° N (Kolar et al. 2005). Map modified from www.theodora.com/maps.

### 2.4.4. Present Uses within the United States

Silver carp are not presently being cultured in the United States, and have only occasionally been cultured in the last 20 years (Kolar et al. 2005). While some believe silver carp have potential as a food fish within the United States (Laird and Page 1996), silver carp are not cultured, largely because of their jumping habits and poor handling qualities during production, harvest, and transport (Kolar et al. 2005).

Due to their ability to efficiently filter suspended material from water, silver carp have been stocked intentionally in some states to improve water quality in lakes, aquaculture ponds, and wastewater systems (Henderson 1978, 1979; Burke et al. 1986; Lieberman 1996). Silver carp can provide effective biological control of algae populations in earthen production ponds by filtering algae, zooplankton, and suspended material from the water. This results in a continuously growing algae bloom, thereby improving the cycling of nutrients within the production pond. Silver carp have also been used in the United States to manage water quality in sewage treatment lagoons, manure lagoons, and reservoirs. Early research in this capacity indicated that facility design greatly determined the overall effect of silver carp on water quality. Silver carp are no longer raised or stocked as biological control agents to improve water quality in the United States.

Commercial harvest of silver carp is increasing in parts of the Mississippi River Basin. The combined annual commercial harvest of bighead and silver carps from the Mississippi and Illinois rivers within Illinois increased from less than 600 kg per year between 1988 and 1992 to in excess of 50,000 kg per year since 1997 (Chick and Pegg 2001). The reported combined commercial harvest of these fishes in 2003 was nearly 60,000 kg from the Mississippi River alone and exceeded 338,000 kg in the Illinois River (Maher 2005). Wild-caught silver carp are occasionally encountered in live fish markets (Kolar et al. 2005). There are on-going efforts by commercial enterprises to develop products and establish markets for wild-harvested silver carp.

### 2.4.5. Potential Adverse Effects

Although direct species interactions are not fully understood and competition is difficult to document in large and dynamic river systems (Kolar et al. 2005), the potential of increasing populations of silver carp to affect native species at all life stages is a concern. Silver carp are believed to affect many native species adversely because they feed on plankton, the primary food source for mussels, larval fish, and several adult fishes (Laird and Page 1996; Fuller et al. 1999). Sampson (2005) found dietary overlap between silver carp with gizzard shad and bigmouth buffalo in the Illinois and Mississippi rivers. Silver carp have the potential to influence large crustacean zooplankton negatively and to alter food web interactions, thereby potentially affecting other native aquatic organisms (Kohler et al. 2005; Sampson 2005). Field studies to investigate a decline in planktivorous species in areas with abundant silver carp populations are lacking.

Feral silver carp have been reported from rivers of the United States since 1981 (Robinson and Buchanan 1988) and are no longer a risk of introducing or spreading nonnative pathogens within their current range. However, additional importation of silver carp into the United States could introduce nonnative pathogens with unknown potential consequences. Scientists have found the Asian tapeworm in silver carp stocks in the former USSR and Philippines (Kolar et al. 2005).

The spread of silver carp has had adverse effects on the commercial fishery in many watersheds (Maher 2005). There is not yet a large market for silver carp in the United States, but in some locations this species is becoming a more substantial portion of the commercial catch (Iowa Department of Natural Resources 2003; Maher 2005; personal communication, Vince Travnichek, Missouri Department of Conservation). Commercial fishers on the Illinois River reported a 124% increase in the harvest of bighead and silver carps (reported as combined harvest) and a 35% decrease in buffalo harvest during 2002. Unless economically viable markets develop, the establishment of large self-sustaining populations of silver carp in the United States may compromise commercial fishing.

Silver carp pose a threat to human safety due to their jumping behavior when startled (Figure 2.4.4). These "flying carp" as some have called them (Skelton 1993; Pflieger 1997) have caused numerous personal injuries and property damage to recreational boaters and fishers (Kolar et al. 2005).

A recently completed environmental risk assessment, completed using methods described by the Risk Assessment and Management Committee (1996), concluded that the overall organism risk potential associated with silver carp was *high* (Kolar et al. 2005). The organism risk potential is based on the probability of silver carp becoming established and the consequences of silver carp establishment. The finding of *high organism risk potential* indicates that silver carp are an organism of major concern and present an unacceptable level of risk. The probability of silver carp establishment if released (*high*) was determined using the following factors: probability of being within the pathway, probability of surviving transit, probability of successfully colonizing and maintaining a population where introduced, and probability of spread beyond the colonized area. The consequence of silver carp establishment (*medium to high*) was determined using the following factors: estimation of economic effect if established, estimation of environmental effect if established, and estimation of effect from social and/or political influences.

**Figure 2.4.4.** Silver carp jumping below the Peoria Lock and Dam on the Illinois River. Picture courtesy of Mike Smith, Illinois River Biological Station, Illinois Natural History Survey.

# CHAPTER 3. MANAGEMENT AND CONTROL OF ASIAN CARPS

Strategies and recommendations developed by the Working Group to accomplish each of the seven goals presented in Section 1.2 are discussed in detail within this chapter. A summary table listing each of the recommendations is presented in Chapter 4 (Table 4.1, page 115).

## Goal 3.1. Prevent accidental or deliberate unauthorized introductions of bighead, black, grass, and silver carps in the United States.

Feral and domestic stocks of Asian carps can be a source of fish for accidental or deliberate unauthorized introductions, and represent a continued risk for spread and range expansion. Active control measures are needed to prevent introduction or range extension, however consideration must be given to the risks and costs/benefits to determine when actions are warranted. To protect the Nation's natural resources, but also allow for a viable aquaculture industry when implemented, a framework for the responsible use of domestic stocks of Asian carps is described. Bighead, black, and grass carps have unique beneficial uses for pond aquaculturists and bighead and grass carps are in commercial trade. Efforts are warranted to develop improved methods for the safe use of these species with the potential for minimal risk to the environment and to derive ecologically safe and economically viable alternatives to their uses.

Prevention recommendations have been developed using a variety of factors (Appendix 6.2). Differences in the biology and use of these various species dictate that each species be addressed individually. Prevention recommendations differ depending upon whether a particular species is absent, present without evidence of a reproducing population, or self-sustaining in the wild. For species in commercial trade, additional factors were considered in developing recommendations, including their intended use (i.e., stocking for biological control or sales to live food markets).

Twenty-two pathways are discussed in this section, with strategies and recommendations following each pathway. Risk levels for each pathway were developed by the prevention section drafting team based on both the likelihood for an introduction to occur and the potential for adverse ecological and/or economic effects (Table 3.1.1). Such risks are important factors in the prioritization of recommended actions to address specific pathways and prevent unauthorized introductions. Risk levels were developed based on the opinion of the prevention section drafting team; however, comments received from the Working Group indicate that there is agreement on only 6 of the 22 pathway risk levels. The major reasons for the disagreement are that a process for consensus within the entire Working Group was not used and there are many nuances concerning each of the pathways (e.g., the risk level of an individual pathway may differ depending on the species of Asian carp considered). The Working Group has not yet addressed the disagreement on the relative risk levels for the identified pathways. Despite the lack of agreement, the risk levels for each pathway are presented in the draft plan. Pathway risk rankings that Working Group members expressed disagreement with are footnoted in the following discussion. To attain consensus in the pathway risk rankings, a formal process could be used early in the implementation phase when recommendations among all sections of the plan are integrated, sequenced, and prioritized (Recommendation 3.7.1.3).

**Table 3.1.1.** Twenty-two pathways identified by the Working Group are grouped according to attributed risk level (highest risk to low risk)[6]. Risk includes both the likelihood for an introduction to occur and the potential for adverse ecological and/or economic effects. Pathways within the different risk levels are ordered alphabetically and not by relative risk.

| Pathway | Risk Level |
|---|---|
| Accidental and deliberate unauthorized releases by individuals | Highest[7] |
| Activities related to wild-caught baitfish | Highest |
| Domestic live transport and distribution of wild-caught fish | Highest |
| Illegal distribution and sales of diploid grass carp as triploid fish | Highest [2] |
| Importation into the United States for "non-commercial use" | Highest [2] |
| Poorly sited aquaculture facilities with Asian carps | Highest |
| Stocking of diploid Asian carps into non-aquaculture waters | Highest |
| Unintentional live transport "in water" by boats, barges, and ships | Highest [2] |
| Unintentional live transport and distribution by natural resources management agencies | Highest [2] |
| Aquarium/hobby industry | Moderate |
| Commercial, domestic transport of live farm-raised Asian carps | Moderate |
| Importation into United States for commercial use | Moderate |
| Incidental inclusion of Asian carps in aquaculture shipments of other farm-raised species to non-aquaculture waters | Moderate |
| Research and educational facilities and projects | Moderate |
| Unintentional shipment of black carp in diploid or untested triploid grass carp stockings | Moderate |
| Incidental inclusion and potential release of Asian carps in "farm raised" baitfish | Low |
| Incidental inclusion of Asian carps in domestic shipments of catfish to fish farms | Low |
| Incidental inclusion of Asian carps in domestic shipments of food fishes | Low |
| Incidental inclusion of Asian carps in international imports of other fishes | Low |
| Intentional release of live, "adult-size" (non-baitfish) Asian carps by boaters, anglers, and bow fishers | Low |
| "Properly" sited aquaculture facilities | Low |
| Stocking of triploid Asian carps into non-aquaculture waters for biological control | Low |

[6] Pathways and risk levels were developed by members of the Prevention Drafting Team. Some Working Group members expressed considerable disagreement with the pathway risk rankings during the most recent review (see attachment 1, Working Group Comments on 10/18/2005 Draft). Numerous comments were received expressing disagreement with proposed risk levels. The Working Group has not yet addressed the disagreement on the relative risk levels for the identified pathways.
[7] Pathway risk level ranking with which Working Group members expressed disagreement.

The pathways are presented by the following subject headings: 1) wild-caught baitfish; 2) stocking for biological control in non-aquaculture waters); 3) boats, barges and ships; 4) natural resources management actions; 5) importation into the United States; 6) aquaculture; 7) live transport; 8) accidental and deliberate unauthorized releases by individuals, 9) aquarium / hobby industry, 10) research and educational institutions; and 11) recreational boaters and fishers.

## 1) ***WILD-CAUGHT BAITFISH***

***PATHWAY:*** **Activities related to wild-caught baitfish**

***RISK LEVEL: Highest Risk***

The transport and release of wild-caught baitfish by anglers and commercial dealers represents one of the highest risk pathways for introduction of Asian carps because live fish can easily be released into new waters. To the untrained eye, juvenile bighead and silver carps can be difficult to distinguish from some species of native baitfish (e.g., gizzard shad). These species have been documented in high abundances in some locations throughout the Mississippi River Basin (e.g., tailwaters and backwaters). Because of their abundance and natural behavior, juvenile bighead and silver carps may be collected with, or in place of, native bait fish. Although less likely to be collected than bighead and silver carps, juvenile grass carp may be collected with wild-harvested native baitfish. Dumping or releasing unwanted, unused live baitfish is a pathway of concern for any aquatic nuisance species. Effective information programs, regulations, and enforcement are all essential components for controlling this pathway.

**Strategy 3.1.1. Take actions to prevent the collection, transport, release, and improper disposal of Asian carps that may be intermixed with live wild-harvested baitfish.**

**Recommendation 3.1.1.1. Assist states develop, promulgate, and enforce regulations that manage the harvest, transport, import, trade, and release of live wild-harvested aquatic bait.**

Dumping or releasing unused live baitfish is a common practice among anglers. Eggs, larvae, and juvenile Asian carps can be transferred rapidly and easily between watersheds or upstream over dams when intermixed with wild-harvested baitfish. A single commercial baitfish dealer potentially can ship baitfish contaminated with Asian carps to locations in multiple states.

State regulations are needed to ensure that baitfish harvest, transport, release, and disposal does not expand existing populations or establish new populations of Asian carps or other nonnative biota. Suggested regulations should address the following:

- States should restrict the use of wild-caught live bait by anglers to the immediate waterbody where collected, including strict specifications regarding the collection of fish from spillways.
- The transport of wild-caught baitfish contaminated with Asian carps or collected from waters known or suspected of having any species of Asian carp should be prohibited by anglers and commercial dealers.

- States should require exporters and importers of live wild-caught bait to implement Hazard Analysis and Critical Control Point planning for all shipments of live baitfish.
- States should develop a list of bait species approved for importation (i.e., "Clean List") to limit the transport and importation of live baitfish to specific approved species.
- States should consider regulations that require shipments of live wild-harvested baitfish to be certified as containing no nonnative or aquatic nuisance species.
- States should explore regulations that address the waters used to transport wild-harvested baitfish to prevent the transport of Asian carp eggs, larvae, and other nonnative biota.
- State regulations should be used to ensure the proper disposal of all unwanted live bait.
- Information awareness campaigns and law enforcement will be needed to support regulations.

**Recommendation 3.1.1.2. Develop and provide information to commercial and recreational baitfish harvesters that will help prevent accidental and deliberate unauthorized introductions of Asian carps.**

An information module and educational materials are needed to assist commercial and recreational baitfish-harvesters in reducing the risk of accidental and deliberate unauthorized introductions of Asian carps. Commercial and recreational baitfish harvesters should be engaged to ensure that their specific education and outreach needs, and how to most effectively meet these needs, are understood.

Currently, training in Hazard Analysis and Critical Control Point planning specific to aquatic nuisance species is provided by both the National Sea Grant College Program (Gunderson and Kinnunen 2004) and the USFWS (http://haccp-nrm.org/) for implementation by the baitfish community, natural resources management agencies, the aquaculture industry, researchers, and enforcement officers. The training could be adapted more specifically for baitfish harvesters in watersheds with Asian carps. Various WATCH cards, fact sheets, and posters are also available for baitfish harvesters. Information materials could be made available with both commercial and sport licenses, at bait shops, marinas, and boat ramps.

## 2) ***STOCKING ASIAN CARPS FOR BIOLOGICAL CONTROL IN NON-AQUACULTURE WATERS***

Note: For the purposes of this plan, the Working Group divided waters into two categories: aquaculture and non-aquaculture waters. Aquaculture waters include those bodies of water that are part of a commercial aquaculture facility, while non-aquaculture waters are inclusive of all other waters, including natural and man-made waters, and open and closed systems.

While bighead, grass, and silver carps have been stocked for biological control in the past, only grass carp are currently stocked for biological control in "non-aquaculture" waters.

***PATHWAY:*** **Stocking of diploid Asian carps into non-aquaculture waters for biological control**

***RISK LEVEL: Highest Risk***

Because diploid and triploid Asian carps are referred to throughout this chapter a brief explanation of these terms is provided here. In the diploid (2n) state, the natural condition for Asian carps, a double set of chromosomes occurs in each cell. Diploid Asian carps have the potential to spawn and establish reproducing populations in the wild. Techniques have been developed to manipulate chromosome sets and develop triploid (3n) individuals with three sets of chromosomes in each cell for the purpose of producing sterile fish. Triploids are morphologically indistinguishable from diploids (Thorgaard and Allen 1987). Induced triploidy leads to varying degrees of sterility in some fish species (Kapuscinski and Patronski 2005) meaning that triploid of some species may successfully reproduce in the wild. Triploid grass carp are functionally sterile and can be considered sterile for management purposes (Allen et al. 1986; Allen and Wattendorf 1987; Thorgaard and Allen 1987; Van Eenennaam et al. 1990; Benfey 1999; Devlin and Nagahama 2002; Nico et al. 2005). Techniques to produce triploid bighead, black, and silver carps have been developed, however the sterility of these fishes has not been evaluated.

**Strategy 3.1.2. Take actions to prevent the stocking of diploid Asian carps into non-aquaculture waters for biological control.**

Bighead and silver carps were stocked in sewage treatment lagoons and natural waters by state and federal agencies in the 1970s, but have not been stocked for biological control in recent decades. Black carp have never been stocked in natural waters for biological control in the United States. Ten states allow stocking diploid grass carp for biological control of nuisance aquatic vegetation (Table 2.3.1, page 21; Dauwalter and Jackson 2005; personal communication, Jill Popham, USFWS).

**Recommendation 3.1.2.1. Encourage states to develop regulations that prohibit the stocking of any diploid Asian carps into non-aquaculture waters for biological control.**

Diploid Asian carps should not be stocked as biological controls in any open waters and regulations to prohibit future stockings of bighead, black, grass, and silver carps are warranted. Scientific information on the effects of reproducing grass carp populations in the Mississippi River Basin can be assembled and distributed to state natural resource agencies in those states which still permit stocking diploid grass carp, to provide those agencies with data that would assist in decision-making relative to sales and use of the diploid fish. Continued stocking of diploid Asian carps is counterproductive to efforts to contain and reduce feral populations. However, triploid grass carp are more expensive than diploids and therefore regulations that prohibit stocking diploid grass carp will create a higher cost for consumers, including state natural resources management agencies and private pond owners. This may be especially true for some limited resource landowners who use grass carp to manage aquatic vegetation in recreational or farm ponds. However, triploid grass carp remain a relatively low-cost alternative compared to other methods of aquatic vegetation control (i.e., chemical or mechanical).

**Recommendation 3.1.2.2. Remove or contain diploid Asian carps that have been previously stocked into non-aquaculture waters for biological control.**

Encourage states to identify where diploid Asian carps have been previously stocked in non-aquaculture waters for biological control. States should evaluate the risk of existing diploid Asian carps introducing or expanding feral populations and determine if measures to contain or remove fish are warranted. Where warranted, containment and/or control measures should be implemented.

***PATHWAY*****: Illegal distribution and sales of diploid grass carp as triploid fish**

***RISK LEVEL: Highest Risk*** [8]

Triploid grass carp are more expensive to produce and are sold at approximately 2-3 times the price of diploid fish (personal communication, Mike Freeze, Keo Fish Farm). Most states that require triploid grass carp for biological control are only able to inspect a small percentage of grass carp shipments within the state. Recent law enforcement cases support the concern that diploid grass carp have been sold fraudulently as triploid fish and stocked into open waters.

Some states employ measures such as the USFWS Triploid Grass Carp Certification and Inspection Program for assurances that shipments of triploid grass carp do not contain diploid fish. Many states attempt to prevent the introduction and establishment of diploid grass carp within their borders, while others do not take effective measures to enforce regulations. Reasons for less than effective enforcement include 1) insufficient numbers of law enforcement personnel; 2) lack of access to the expensive, sophisticated equipment required to determine ploidy; or 3) diploid grass carp are regarded with low concern because diploid populations are already widespread in many watersheds in the United States.

The economic incentive for people to fraudulently sell diploid grass carp as triploids, accompanied by a frequent lack of enforcement, perpetuate the potential for unauthorized introductions of diploid grass carp.

**Strategy 3.1.3. Take actions to prevent illegal sale, shipping, and stocking of diploid grass carp as triploid grass carp.**

**Recommendation 3.1.3.1. Encourage states that allow the legal importation of grass carp to adopt consistent, uniform regulations that allow only certified triploid grass carp to be shipped or stocked.**

Consistent regulations requiring shipment and stocking of certified triploid grass carp only, combined with state enforcement, could eliminate most of the sources of fraudulent sales. Possession of diploid grass carp can be prohibited or restricted through permits to licensed or authorized triploid grass carp producers. In the absence of markets for diploid fish, the majority of distributors, wholesalers, and retailers will not have a need to possess, or be tempted to fraudulently sell, diploid grass carp.

States should work together, possibly through the International Association of Fish and Wildlife Agencies, to ensure that unauthorized stockings of diploid grass carp are effectively prevented. Diploids that escape into the wild in one state may migrate to a state that is effectively preventing or controlling the establishment of feral populations within or along its borders.

**Recommendation 3.1.3.2. Encourage states to conduct routine and random inspections of all live grass carp shipments within the state.**

[1] Pathway risk level ranking with which Working Group members expressed disagreement.

Shipments of live grass carp frequently enter or move within many states. All states should be encouraged to develop and enforce regulations regarding sales, shipping, and stocking grass carp. Natural resources management agencies should require the inspection of shipments of live grass carp (and other Asian carps) to enforce and encourage compliance with existing or new regulations.

Live fishes are a commodity, and inspections will require carefully planned and executed procedures to prevent the loss of capital. Liability should not prevent the inspection of shipments, but should promote the use of good judgment, and development and testing of efficient inspection procedures to prevent delays and loss of product.

**Recommendation 3.1.3.3. Encourage the USFWS to provide ploidy determination for states conducting inspections of grass carp shipments.**

The USFWS Triploid Grass Carp Inspection and Certification Program does not have an enforcement component and is dependent upon states to inspect shipments and enforce state regulations regarding importation of the species. However, many states do not have the equipment or expertise to determine ploidy of fish in inspected shipments and may need assistance to provide for enforcement of regulations.

The USFWS should consider providing regional assistance to states, perhaps through National Fish Technology or Fish Health Centers. The USFWS currently has the expertise and equipment to determine grass carp ploidy in some Regions and the capability for development in all Regions. The USFWS was authorized by Congress (Public Law 104-40; November 1, 1995) to "charge reasonable fees for expenses to the federal government for triploid grass carp certification inspections." Triploid grass carp producers who choose to participate in the Triploid Grass Carp Inspection and Certification Program are charged fees based on the numbers of fish inspected, plus travel costs for the inspector. Contingent upon demonstration of economic feasibility, it is recommended to build additional fees into the Triploid Grass Carp Inspection and Certification Program to reimburse the USFWS for ploidy determination as part of random state inspections of interstate shipments of certified triploid grass carp.

***PATHWAY*: Unintentional shipment of black carp in diploid or untested triploid grass carp stockings**

***RISK LEVEL: Moderate Risk***

Black and grass carps are similar in appearance, especially when the fish are small. Although black carp are produced legally at a very limited number of facilities, it is common for facilities that produce black carp to also produce grass carp.

When produced and sold in large numbers, the possibility does exist for some mixing of black and grass carps. The extent of such occurrence is unknown. Release of black carp in a shipment of grass carp is a high-risk to the environment given that stocking often occurs in public waters. Black carp contained in the shipment and subsequently released would constitute a range expansion of feral populations of this species. The shipment and stocking of diploid grass carp and uncertified triploid grass carp present the greatest opportunity for unintentional stockings of black carp. Diploid and uncertified triploid grass carps are handled in bulk at harvest and individual black carp intermixed with these fish could go undetected. The unintentional stocking of black carp in a shipment of certified triploid grass carp is much less likely given that each fish is individually screened for ploidy. The nuclear diameters of blood cells from triploids of both black and grass carps and of diploids of both species are essentially the same according to flow cytometer data and coulter counter data (personal communication, Mike Freeze, Keo Fish Farm). A black carp would thus have to be misidentified by screeners as a grass carp and be a triploid individual for it to be included in the lot of triploid grass carp.

Although the production of black and grass carps at the same facility provides a pathway for the unintentional introduction of black carp, the pathway can be managed to reduce this risk.

**Strategy 3.1.4. Take actions to prevent the shipment of live black carp in grass carp shipments.**

This strategy is addressed by Recommendation 3.1.3.1: Encourage states that allow the legal importation of grass carp to adopt consistent regulations that allow only certified triploid grass carp to be shipped or stocked.

***PATHWAY*: Stocking triploid Asian carps into non-aquaculture waters for biological control**

***RISK LEVEL: Low Risk*** [9]

Grass carp can cause secondary effects on biological communities as a consequence of vegetation changes (Bain 1996). The use of triploid grass carp is not without ecological risks, although those risks are greatly reduced compared to using diploid grass carp. Thirty-eight states authorize triploid grass carp stocking for biological control of nuisance aquatic vegetation and ten allow diploids, however twelve states (and the District of Columbia) prohibit the use of grass carp in their waters (Table 2.3.1, page 21; Dauwalter and Jackson 2005; personal communication, Jill Popham, USFWS). Grass carp are migratory and have the potential to affect non-target waters long distances from their place of introduction into open systems. Inconsistent state regulations can result in unintended consequences in states that share connected waters.

As previously discussed in Strategy 3.1.2, bighead and silver carps were stocked in non-aquaculture waters for biological control during the 1970's. Actions are warranted to address past and future stocking of all Asian carps in non-aquaculture waters for biological control.

**Strategy 3.1.5. Take actions to address stocking triploid Asian carps into non-aquaculture waters for biological control.**

> **Recommendation 3.1.5.1. Encourage states to prohibit stocking triploid bighead, black, and silver carps for biological control in non-aquaculture waters.**
>
> Bighead, black, and silver carps are not currently stocked into non-aquaculture waters for biological control and states should develop regulations to prohibit future stocking.
>
> **Recommendation 3.1.5.2. Encourage states to allow stocking triploid grass carp for biological control in non-aquaculture waters only within watersheds where grass carp are already present in the wild.**

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[9] Pathway risk level ranking with which Working Group members expressed disagreement.

Stocking triploid grass carp should be prohibited in watersheds where grass carp are not present in the wild to prevent introductions into currently uninvaded waters. In watersheds where grass carp are present, states should restrict stocking grass carp for biological control in non-aquaculture waters to certified triploids only to limit potential range expansion of reproducing populations. Implementing this recommendation may adversely effect some limited-resource landowners who might otherwise use grass carp to manage aquatic vegetation in recreational or farm ponds. Implementation of this recommendation may also encourage greater use of chemical herbicides.

**Recommendation 3.1.5.3. Remove or contain triploid Asian carps that have been previously stocked in non-aquaculture waters within watersheds where the fish are not currently self-sustaining in the wild.**

Encourage states to identify waters where triploid Asian carps have been stocked in non-aquaculture waters, but within watersheds where the fish are not currently self-sustaining in the wild. States should evaluate the risk of triploid Asian carps escaping from stocked waters and determine if measures to contain or remove the fish are warranted. Implementation of this recommendation may have the same adverse effects as those identified for Recommendation 3.1.5.2.

**Strategy 3.1.6. Take actions to ensure that stocking triploid grass carp for biological control does not result in accidental or deliberate unauthorized introductions of diploid grass carp.**

**Recommendation 3.1.6.1. The USFWS should seek an independent scientific review and evaluation of the Triploid Grass Carp Inspection and Certification Program.**

An “overwhelming support from state conservation and fish and game agencies from about 20 states” in the 1990s resulted in Congress passing the Triploid Grass Carp Certification Act of 1995 (Mitchell and Kelly 2006). Twenty-seven states currently rely on the USFWS Triploid Grass Carp Inspection and Certification Program (Program) to prevent accidental or deliberate unauthorized stockings of diploid grass carp as triploids (Table 2.3.1, page 21; personal communication, Jill Popham, USFWS). Throughout this plan, the Working Group recommends the planned use of triploid grass carp within watersheds where grass carp are present in the wild. The effective use of triploids to prevent self-sustaining populations from becoming established is dependent upon the effectiveness of inspection programs to identify and remove diploid fish.

The USFWS and triploid grass carp inspectors have worked together to develop reasonable and effective standards for the Program. An independent scientific review is warranted to evaluate the effectiveness of this widely used Program and to recommend reasonable actions that would improve the integrity, efficiency, and effectiveness of the Program. The USFWS should request an independent scientific review of the Program from the American Fisheries Society and the United States Aquaculture Society or other appropriate groups. Recognized experts in triploidy induction and reproductive physiology of grass carp should be included on the review team. Producers and natural resources managers alike favor a program of high integrity and effectiveness that provides reliable assurances to the receiving states.

**Recommendation 3.1.6.2. Develop and provide information on the USFWS Triploid Grass Carp Inspection and Certification Program.**

An information module should be developed on the Program, its operation, and its effectiveness at protecting our natural resources. The primary audiences for this module are natural resources managers, fish farmers, and the general public. The module should include a presentation on the Program that can be delivered to natural resources managers at regional and professional society meetings. In addition, state natural resources management agencies should be actively involved in meetings of producers and inspectors. Fish farmers and the public often ask why triploid grass carp are either recommended or required for biological control as their cost is much greater than diploids. This is especially true throughout portions of the Mississippi River Basin where feral grass carp have established reproducing populations in numerous rivers.

An effective module will increase participation and understanding of the need, benefits, and limitations of the Program among the public and natural resources management agencies. An improved understanding by consumers should result in increased support and compliance with efforts to prevent introductions of diploid grass carp. Eliminating the source of fertile grass carp that may escape into the wild is an important step toward the control of feral populations.

The standards for the Program are available on the Internet at http://www.fws.gov/warmsprings/FishHealth/frgrscrp.html. This web site could be expanded to provide additional information developed as part of the Program informational module.

The USFWS should be the lead agency to develop this module, with participation and assistance from triploid grass carp producers. Development of this module should be coordinated by USFWS employees that participate in the Program.

## 3) *BOATS, BARGES, AND SHIPS*

***PATHWAY*: Unintentional live transport "in water" by boats, barges, and ships**

***RISK LEVEL: Highest Risk*** [10]

Boats, barges, and ships are potential vectors for the distribution and expansion of aquatic nuisance species. Commercial and recreational vessels certainly can transport and release planktonic organisms, nuisance plants, and macroinvertebrates; however, their potential for the transport and release of viable Asian carp eggs or larvae is uncertain. More than 25,000 miles of navigable rivers and canals, of which 12,000 miles are operated and maintained by the federal government as commercial waterways, provide access between numerous interconnected watersheds in 41 states (Tennessee-Tombigbee Waterway Development Authority 1999). Commercial and recreational vessels, using the Inland Waterway System, are a potential pathway for expanding the distribution and range of feral Asian carps. It is uncertain if viable Asian carp eggs and larvae could be unintentionally transported beyond dispersal barriers (Recommendation 3.2.2.3) by commercial or recreational vessels. Research is needed to fully understand the potential for watercraft to transport viable Asian carp eggs and larvae to new waters, including waters upstream of dispersal barriers.

[10] Pathway risk level ranking with which Working Group members expressed disagreement.

**Strategy 3.1.7. Take actions to prevent the transport and release of Asian carps by boats, barges, and ships.**

**Recommendation 3.1.7.1. Investigate fully the risks associated with ballast water transfers or other means of water transfer by barges and ships, and live well transfers by boats.**

This potential threat warrants immediate actions to understand the full risk potential that boats, barges and ships pose as a vector for expanding feral populations of Asian carps. Bilge, seep, and live well waters are generally taken on in one location and pumped out or released in another, potentially miles or watersheds away. If viable eggs and larvae can be transported and released through bilge, seep, or live well waters, this pathway has the potential to disperse Asian carps throughout the Inland Waterway System. The transfer of water by commercial and recreational vessels must be researched and understood to recommend management actions to address this potential pathway.

**Recommendation 3.1.7.2. Inform boaters, barge operators, and others of the risks of moving infested water and encourage voluntary actions to reduce this risk.**

Informing commercial and recreational vessel operators of the risks of moving infested water is warranted to encourage voluntary actions that reduce the risk of unintentional transfers and introductions. Continue to seek partners for, and spread the message of, the national "Stop Aquatic Hitchhikers!" campaign.

## 4) ***NATURAL RESOURCES MANAGEMENT ACTIONS***

***PATHWAY*: Unintentional live transport and distribution by natural resources management agencies**

***RISK LEVEL: Highest Risk*** [11]

Natural resources management agencies routinely sample aquatic organisms and their habitat, and implement management actions to sustain ecosystems. The nature of the biologist's job involves working in the ecosystem, which presents risks to species and their habitats. Among these risks is the potential for management actions to provide a pathway of introduction to aquatic nuisance species, including Asian carps. Natural resources management actions are considered a likely pathway because of the frequency with which biologists and technicians come into contact with Asian carps and the potential for biologists to travel throughout and among different waters in a short period of time. The potential to transfer eggs and larvae unintentionally in residual waters, and to misidentify juvenile fish, is a risk that natural resources managers must recognize and work to prevent.

**Strategy 3.1.8. Take actions to prevent the unintentional transport, release, or disposal of Asian carps by natural resources managers during management activities.**

**Recommendation 3.1.8.1. Natural resources managers should employ pathway management tools, such as Hazard Analysis and Critical Control Point planning in**

[11] Pathway risk level ranking with which Working Group members expressed disagreement.

**the review of Standard Operating Procedures, to prevent introductions of Asian carps through natural resources management related pathways.**

Natural resources managers should review Standard Operating Procedures and adapt pathway management tools where necessary to reduce the risk of unintentionally transferring Asian carps, and other aquatic nuisance species. Hazard Analysis and Critical Control Point planning is a pathway management tool adopted by natural resources management agencies to identify risks of aquatic nuisance species introductions and to implement procedures that prevent the unintentional spread of species.

**Recommendation 3.1.8.2. Develop and provide information to natural resources managers and field staff that will help prevent unintentional introductions and spread of feral Asian carps.**

An information module and outreach products to help reduce the risk of accidental or deliberate unauthorized introductions by natural resources managers is needed. These groups can include state, federal, international, and tribal agencies, private (non-governmental) organizations, and businesses. Natural resources managers, particularly field biologists and technicians, must be adequately trained in the identification of all species and life stages of Asian carps, as well as, Hazard Analysis Critical Control Point planning.

Natural resources managers must seek and share current information on the distribution of feral Asian carp populations. Mechanisms for information exchange must be identified, developed, and utilized. Natural resources managers should be informed about Asian carps and other aquatic nuisance species in the locations where work is being conducted. Informed and trained natural resources managers not only reduce the risk of unintentional introductions, but are effective sentinels for early detection.

Hazard Analysis Critical Control Point planning is currently implemented by the USFWS at many national fish hatcheries and fisheries management assistance field offices with training offered nationally to all natural resources management agencies (http://haccp-nrm.org/). This training could be used more specifically for technicians and biologists in watersheds with Asian carps as a long-term solution to preventing unintentional release. Opportunities to participate in these training programs are currently available and should be utilized immediately. Field biologists and technicians should receive copies of WATCH cards and fact sheets, and participate in Asian carp presentations.

## 5) ***IMPORTATION INTO THE UNITED STATES***

*Note: The importation of Asian carps into the United States is divided into two categories for this plan - commercial use and non-commercial use.*

***PATHWAY:*** **Importation into United States for "non-commercial use"**

***RISK LEVEL: Highest Risk*** [12]

[12] Pathway risk level ranking with which Working Group members expressed disagreement.

Little is known about non-commercial importation and importers. Some possible reasons for live import of Asian carps for non-commercial uses include human consumption, deliberate unauthorized stocking or release, and collection by aquarium or water garden hobbyists. The Internet and mail service makes it easy to buy, sell, and even import live fish, including Asian carps. Importers, through the Internet, catalog, and other means, may be unaware of laws and problems associated with Asian carps. Therefore, this pathway may present unique issues or problems for prevention actions. Small shipments of Asian carps may be more difficult to detect, and Internet sellers may be more difficult to inform and regulate. The extent of this pathway is unknown, but the potential distribution and release of Asian carps threatens all watersheds in the United States.

**Strategy 3.1.9. Take actions to prevent the importation of bighead, black, grass, and silver carps into the United States for "non-commercial use" (e.g., Internet sales and direct shipments from foreign sources to end users).**

**Recommendation 3.1.9.1. Prohibit international importation of Asian carps for non-commercial use under federal and state regulations, except for research purposes under a controlled permit.**

Imports of live fish and eggs into the United States for non-commercial purposes must be declared to the United States Customs and Border Protection (USCBP) Agency, USFWS, or other federal agency if the intended use is for human consumption. State regulations and permits for the importation of Asian carps will reinforce federal regulations and help ensure that appropriate safeguards against release into the wild are in place.

All states should be urged to maintain or develop state regulations that prevent future importation of all Asian carps, except for research purposes. Any importation for research purposes should be allowed only under permits to institutions that have been specifically designed and constructed to confine the fish and prevent the accidental escape of all life stages. States, USFWS, and other federal agencies should work collaboratively in preventing the import of state prohibited species.

**Recommendation 3.1.9.2. Inform USFWS Law Enforcement Officers, other federal inspectors, and state conservation law enforcement officers about laws that apply to the import of live Asian carps, the importance of preventing the illegal import of Asian carps, and Asian carp identification.**

An information awareness campaign is needed to alert USFWS Officers, other federal inspectors, and state conservation law enforcement officers that Asian carps are nuisance species and regulations may apply to their importation. Further, federal inspectors and state and federal officers should establish regular dialogue and work in partnerships to prevent illegal imports of Asian carps. It will be necessary to develop and maintain current information that lists which Asian carps are legal or illegal to import into individual states, and applicable federal laws.

**Recommendation 3.1.9.3. Inform potential importers of applicable state and federal laws and associated risks with international shipments of live Asian carps.**

An information module and outreach materials are needed to alert importers to the fact that Asian carps are nuisance species, regulations may apply to their importation, and of the potential adverse effects of imported fish to wild and/or captive fishes. Fish importers should be engaged to ensure that their specific education and outreach needs, and how to most effectively meet these needs, are understood. Implementing this recommendation will enable agencies to deter importers from legally or illegally importing Asian carps. It will be necessary to develop and maintain current information that lists which Asian carps are legal or illegal in individual states, and applicable federal laws.

**Recommendation 3.1.9.4. Increase the numbers of trained USFWS Law Enforcement Officers and increase physical inspections of international shipments of live fish and eggs at designated or non-designated ports of entry.**

All imports of live fish should be physically screened by trained USFWS Officers to ensure that only the species declared are shipped. An increase in the number of trained USFWS Officers is warranted due to the number of live fish imports into the United States. At a minimum, increased random physical inspections and screenings for exact matches to declared contents should be conducted. If Asian carps or other aquatic nuisance species are detected in a shipment but are not declared or are prohibited, the shipment should be denied entry into the United States. State regulations banning the importation of Asian carps would also help USFWS Officers to seize shipments containing Asian carps in violation of a receiving state's laws.

***PATHWAY*: Importation into United States for commercial use**

***RISK LEVEL: Moderate Risk*** [13]

There have been only a limited number of legal importations of Asian carps for commercial aquaculture use in the United States (personal communication, Mike Freeze, Keo Fish Farm). Currently, there are fertile stocks of bighead, grass, and silver carps available from the wild and bighead, black, and grass carp broodstock are available from a few commercial hatcheries. Illegal imports are of concern because of the risk that appropriate safeguards to avoid accidental or deliberate unauthorized introductions will not be used. In addition to illegal imports, legal importation to facilities outside of the established ranges of Asian carps in the wild presents risks of introduction or range expansion.

**Strategy 3.1.10. Take actions to prevent the illegal importation and prohibit the legal importation of live bighead, black, grass, and silver carps for commercial use in the United States.**

In addition to the following recommendation, this pathway is further addressed by Recommendations 3.1.9.2, 3.1.9.3, and 3.1.9.4.

**Recommendation 3.1.10.1. Develop federal and state regulations that prohibit importations of live bighead, black, grass, and silver carps for commercial use in the United States.**

Prohibiting the international importation of Asian carps will not have an adverse effect on aquaculture related businesses. The aquarium and hobby trades are potential importers

[13] Pathway risk level ranking with which Working Group members expressed disagreement.

of Asian carps; however, Asian carps rarely are found in the aquarium trade and, thus, there should be no adverse effects to the pet industry.

***PATHWAY*: Incidental inclusion of Asian carps in international imports of other fishes**

***RISK LEVEL: Low Risk*** [14]

Millions of live fish are imported annually into the United States for both commercial and non-commercial uses. Imported shipments of live fish and eggs into the United States must be declared to the USCBP, USFWS, or other federal agency and inspected at a designated port of entry by a USFWS Officer, except under special permit. However, most inspections focus on import paperwork only and do not include a physical inspection of the package. Declared shipments must indicate the scientific names, country of origin, and quantity for each species in the shipment. Limited physical inspections primarily screen for humane shipment of live fish, and for threatened and endangered species or injurious wildlife. Physical inspections of all imports are needed to verify the contents of shipments with paper work declarations.

Each shipment of live fish into the United States provides an opportunity for non-target species, including Asian carps and other aquatic nuisance species, to enter the country. Actions are warranted to provide some level of Quality Assurance and Quality Control that importations do not contain non-target species.

**Strategy 3.1.11. Take action to prevent the incidental inclusion of live Asian carps in international imports with other fishes.**

This pathway is addressed by Recommendations 3.1.9.1, 3.1.9.2, 3.1.9.3, 3.1.9.4, and 3.1.10.1.

## 6) ***AQUACULTURE***

***PATHWAY:* Poorly sited aquaculture facilities with Asian carps**

***RISK LEVEL:* Highest Risk**

Aquaculture, the controlled cultivation of aquatic organisms, is a form of agriculture in which aquatic plants and animals are raised for a variety of uses. Farmers, whether of fish, livestock, or row crops, have a vested interest in keeping their livestock (both aquatic and terrestrial) under control on their farm and preventing their escape to the wild. One way that fish could escape from a fish farm or hatchery is by swimming in a stream of water that discharges from the farm and enters an open, natural waterway. This assumes that there is a connection between the point of discharge from a pond and the open body of water. A second way that fish could escape is during severe flood events. Poorly sited, high risk, aquaculture facilities are those with ponds that are 1) connected to or dependent on open, natural bodies of water or 2) subject to flooding. There is a high-risk that Asian carps will escape from poorly sited facilities to the wild due to the lack of adequate safeguards to prevent escape, the volume of water flowing from the production unit, or because production units are prone to flooding.

Most commercial pond aquaculture facilities have incorporated advances in water quality management which have demonstrated that water exchange is not an effective way to maintain

[14] Pathway risk level ranking with which Working Group members expressed disagreement.

water quality in earthen ponds; aerators are more effective in maintaining oxygen levels and are more economical (Boyd 1990). Many types of efficient aeration devices are used on fish farms today and pond fish farmers do not exchange water as a regular means to manage water quality.

Many states have regulations that affect the siting of aquaculture facilities to prevent escape of farmed animals and minimize effluent discharge. Loss of fish stocks directly reduces farm revenue and is an incentive for businesses to minimize losses. Losses from a poorly sited facility can lead to new or expanded populations in the wild.

**Strategy 3.1.12. Take actions to prevent the unintentional escape, release, or improper disposal of Asian carps from aquaculture facilities at poorly sited locations.**

**Recommendation 3.1.12.1. Urge the development and enforcement of state regulations that prohibit the production of Asian carps at poorly sited facilities.**

As previously defined, poorly sited facilities are those with connections to open waters or subject to flooding. States should prohibit the future stocking of Asian carps on any poorly sited facility. Regulations should define acceptable parameters, including site-specific conditions such as: 1) protection from flooding available either by the system of containment levees along river systems, pond levee elevations, or not locating facilities in a flood plain; 2) frequency and volume of discharges; and 3) controls to prevent escapes. By reducing the number of poorly sited facilities, the potential for additional escapes to the wild will be reduced. Poorly sited facilities that are able to upgrade within acceptable parameters would no longer be considered a high-risk facility and states may choose to permit the use Asian carps within other provisions of the plan.

**Recommendation 3.1.12.2. Develop and provide information to Asian carp producers and growers that will help upgrade poorly sited facilities such that they are no longer high-risk to contain farm-raised carps and prevent accidental introductions.**

Work with Asian carp producers and growers to understand their operational activities and practices and identify information needs that will result in a reduced risk of accidental and deliberate unauthorized releases from these facilities. This audience should include both hatcheries used for distribution and those that culture Asian carps for commercial purposes. Information should assist poorly sited facilities upgrade, if possible, such that they are no longer high-risk and are able to produce Asian carps within other provisions of the plan.

Several relevant activities have been or currently are being implemented. University and aquaculture Cooperative Extension educators, trade publications, trade associations, and the media have alerted growers on how their activities have been perceived. Some university and aquaculture Cooperative Extension service educators and trade associations have provided information to improve production practices (e.g., http://aquanic.org). States within the Mississippi River Basin regulate the culture, possession, or sale of exotic species and require aquaculture facilities to acquire exotic species permits and specific farm design, operation, and management practices to reduce exotic species risks and occurrences (Environmental Law Institute 2002).

A major obstacle for this recommendation is effective communication between growers, natural resources managers, and educators. The challenge arises from the diversity of locations, various fish raised, different management practices, and other factors. It is essential that growers be identified and included in the collaborative process.

**Strategy 3.1.13. Develop an active research initiative to identify alternatives to the use of Asian carps.**

**Recommendation 3.1.13.1. Form a coordinating research group that includes representatives from the aquaculture industry, the ethnic retail grocer industry, marketing scientists and developers, aquaculture scientists, and natural resources managers to focus research efforts on the highest priority alternatives to the use of Asian carps.**

Natural resources management agencies and aquaculture scientists should work with the aquaculture industry and marketing scientists to find environmentally safe alternatives to the use of Asian carps by the aquaculture industry. A focused multidisciplinary research effort will accelerate progress towards the identification of economically feasible alternatives. Identifying sources of funding and coordinating research efforts will contribute to more rapid implementation of research programs. The coordinating group will play a key role in advancing research goals and initiatives.

**Recommendation 3.1.13.2. Develop an information module on economic and effective alternatives to replace the use of bighead and black carps on aquaculture facilities.**

The module should first be intended to identify the need for alternatives and the need for stakeholders to work together to identify alternatives. The information module should be modified as potential alternatives are identified to encourage use of the identified alternatives.

***PATHWAY*: Incidental inclusion of Asian carps in aquaculture shipments of other farm-raised species to non-aquaculture waters**

***RISK LEVEL: Moderate Risk*** [15]

Catfish and other species are sold live for use in non-aquaculture waters. If Asian carps are present in the aquaculture ponds from which the catfish and other species are harvested, it is possible to transport them to fishing ponds and lakes. Erdman (1984) reported that two silver carp were apparently stocked into golf course ponds as fingerlings mixed with grass carp. Other species have been accidentally introduced into new waters via public and private stockings (Simpson and Wallace 1982; Zuckerman and Behnke 1986). However, any Asian carps that might be present tend to be much larger than the other fish and are removed from the net prior to loading out fish. Size differences make the Asian carps relatively easy to detect, and removing them is a standard practice. In-pond grading technology is also available to replace hand sorting on farms.

In addition to the following strategy, this pathway is further addressed by Strategy 3.1.13.

[15] Pathway risk level ranking with which Working Group members expressed disagreement.

**Strategy 3.1.14. Take actions to prevent the incidental inclusion of Asian carps in aquaculture shipments of other farm-raised species to non-aquaculture waters.**

**Recommendation 3.1.14.1. Review Standard Operating Procedures and recommend Best Management Practices that include requirements for suppliers and purchasers to conduct inspections of fish prior to shipment and release.**

A review of Standard Operating Procedures on farms that ship fish to non-aquaculture waters would provide a basis for determining whether there are areas for which Best Management Practices would be useful. Any development of Best Management Practices should occur through a participatory process with growers, live-haulers, university researchers, extension personnel, natural resources management agencies, and the appropriate industry associations to ensure maximum compliance. Purchasers of fish for stocking, including natural resources management agencies and non-governmental organizations should be encouraged to screen or inspect shipments prior to release. Any inspection process developed should consider issues related to implementation that may result in lengthy delays and losses of fish.

**Recommendation 3.1.14.2. Encourage states to develop regulations that allow for random inspections of live fish shipments into and within the state.**

Anecdotal information suggests that Asian carps may have been introduced incidentally in shipments of other fish stocked into fishing lakes. In the absence of state inspections during shipment or stocking, it is difficult to know if this has occurred. Anecdotal information and common sense are often all that is available to identify a stock contamination problem. Random inspections of live fish shipments into and within the state would provide a basis for determining if any problems exist. Live fishes are a commodity, and inspections will require carefully planned and executed procedures to prevent the loss of capital. Any inspection process developed should consider liability for damages to shipments if the inspection process results in lengthy delays or losses of fish. However, liability should not prevent the inspection of shipments, but should promote the use of good judgment and development and testing of efficient inspection procedures to prevent delays and loss of product.

**Recommendation 3.1.14.3. Prohibit the use of surface waters containing Asian carps from being used in aquaculture facilities unless effective treatment is in place with a monitoring program.**

Some older culture facilities were constructed based on surface water supplies. If the surface water comes from waters with reproducing populations of Asian carps, it is very likely that the culture waters could include Asian carp larvae and fry. If the facility is a state or federal hatchery used for stocking programs, or a commercial hatchery selling fish for stocking into fishing ponds and lakes, the Asian carp fry or larvae could be inadvertently included and result in unintentional stocking of new waters. Regulating agencies should prohibit aquaculture facilities from using surface waters that contain Asian carps, or require effective water treatment and water monitoring programs to prevent the transfer of Asian carps to other waters.

***PATHWAY*: "Properly" sited aquaculture facilities**

***RISK LEVEL: Low Risk*** [16]

Most properly sited commercial aquaculture ponds are constructed on land previously used for crops such as cotton or soybeans. Groundwater is the principal water source used. Wells are the preferred source because well water avoids disease problems, the majority of variable water quality conditions, and the potential for contaminants associated with many surface waters. Most pond facilities generally discharge water fewer than 30 days per year and are therefore not considered Concentrated Aquatic Animal Production facilities (i.e., point sources of pollution) subject to the National Pollutant Discharges Elimination System permit system (http://www.epa.gov/fedrgstr/EPA-WATER/2004/August/Day-23/w15530.htm). Catfish foodfish ponds are usually not drained for periods of 7-10 or more years since it is not economical to do so and the earthen ponds themselves function as a very effective waste treatment system. Engle and Valderrama (2002) estimated that 17-28% of the cost of raising catfish foodfish is a result of the natural waste treatment function of earthen ponds. When drained, pond effluents typically flow through systems of drainage ditches, including many that are ephemeral, before reaching natural waters.

Most states have regulations that affect the siting of aquaculture facilities. These regulations were developed to prevent escape of farmed animals, and in some cases minimize effluent discharge. Properly sited facilities conform to these regulations and have adopted site-specific practices required to maintain control over their stocks of fish. These include selecting sites that are protected from flooding either by the system of containment levees along river systems, by pond levee elevations, or by not being located in a floodplain.

In addition to the following strategy, this pathway is further addressed by Strategy 3.1.13.

**Strategy 3.1.15. Reduce potential risks of continued use of Asian carps on properly sited aquaculture facilities to the environment.**

**Recommendation 3.1.15.1. Review Standard Operating Procedures and develop Best Management Practices for "properly" sited aquaculture facilities.**

Employ a stakeholder participatory process, led by university Cooperative Extension specialists, Sea Grant specialists, scientists associated with Regional Aquaculture Centers, and others, with expertise in aquaculture to develop a document that describes current Standard Operating Procedures for properly sited aquaculture facilities. The document should describe the appropriate use of redundant containment measures to prevent escapes of farm-raised carps. In the event areas for improvement are identified, industry associations will be encouraged to work with this group of scientists to develop Best Management Practices to address any issues. This document would also serve to educate those unfamiliar with current Standard Operating Procedures on commercial aquaculture farms with Asian carps.

**Recommendation 3.1.15.2. Encourage states to prohibit the use of grass carp on aquaculture facilities within watersheds where grass carp are not present in the wild.**

[16] Pathway risk level ranking with which Working Group members expressed disagreement.

To prevent introductions and range expansion of grass carp in the wild, states should prohibit the use of grass carp on aquaculture facilities within watersheds where grass carp are absent. If a state allows the use of grass carp within a watershed where grass carp are not present in the wild despite the recommendation to prohibit their use, then only certified triploids should be permitted with appropriate controls for containment (Recommendation 3.1.15.1).

**Recommendation 3.1.15.3. Encourage states to restrict the use of grass carp to certified triploids only on aquaculture facilities within watersheds where grass carp are present but not reproducing.**

If a state allows the use of grass carp within watersheds where grass carp are present in the wild, then only certified triploids should be permitted with adequate and redundant controls to prevent escape. If a state allows the use of diploid grass carp, diploid grass carp should only be permitted with adequate and redundant controls to prevent escape (Recommendation 3.1.15.1).

Scientists associated with Regional Aquaculture Centers, university Cooperative Extension scientists, and Sea Grant Extension scientists should be encouraged to initiate educational programs to encourage aquaculture facilities to use only certified triploid grass carp in all aquaculture applications. This initiative will provide a redundant measure to the risk of escape from properly sited aquaculture facilities.

**Recommendation 3.1.15.4. States should encourage the use of only certified triploid grass carp on aquaculture facilities within watersheds where grass carp are self-sustaining in the wild.**

If a state allows the use of grass carp within watersheds where grass carp are self-sustaining in the wild, then states should encourage the use of only certified triploids. If a state allows the use of diploid grass carp despite the recommendation to use only triploids, diploid grass carp should only be permitted with adequate and redundant controls to prevent escape (Recommendation 3.1.15.1).

Scientists associated with Regional Aquaculture Centers, university Cooperative Extension scientists, and Sea Grant Extension scientists should be encouraged to initiate educational programs to encourage aquaculture facilities to use only certified triploid grass carp in all aquaculture applications. This initiative will provide a redundant measure to the risk of escape from properly sited aquaculture facilities.

**Recommendation 3.1.15.5. Verify functional sterility of triploid bighead carp and develop a triploid certification program for bighead carp.**

Commercial fish farmers have produced triploid bighead carp using techniques similar to those used to produce triploid grass carp (personal communication, Mike Freeze, Keo Fish Farm); however, the functional sterility of these fish has not been evaluated. If triploid bighead carp are proven functionally sterile, a triploid certification program would provide a mechanism to test individual fish for assurances that diploids will not be shipped. However, research is also needed to determine if triploid bighead carp are an economically viable substitute for diploids. If proven economically viable, sterile bighead carp would be a reasonable alternative to diploids for their continued use on properly sited aquaculture facilities within watersheds where bighead carp are currently self-sustaining.

**Recommendation 3.1.15.6. Encourage states to prohibit the use of bighead carp on aquaculture facilities within watersheds where bighead carp are not self-sustaining in the wild.**

To prevent introductions and range expansion of bighead carp in the wild, states should prohibit the use of bighead carp on aquaculture facilities within watersheds where bighead carp are not self-sustaining in the wild. If a state allows the use of bighead carp despite the recommendation to prohibit their use, then only certified triploids should be permitted with adequate and redundant controls to prevent escape (Recommendation 3.1.15.1). The recommendation to allow certified triploid bighead carp is dependent upon research to determine that triploid bighead carp are functionally sterile and the implementation of a triploid inspection and certification program (Recommendation 3.1.15.5).

**Recommendation 3.1.15.7. Encourage states to restrict the use of bighead carp on aquaculture facilities within watersheds with self-sustaining populations to certified triploids only.**

States that allow the use of bighead carp on aquaculture facilities within watersheds where bighead carp are self-sustaining in the wild should encourage the use of only certified triploids. If a state allows the use of diploid bighead carp despite the recommendation to use only triploids, diploid bighead carp should only be permitted with adequate and redundant controls to prevent escape (Recommendation 3.1.15.1).

Scientists associated with Regional Aquaculture Centers, university Cooperative Extension scientists, and Sea Grant Extension scientists should be encouraged to initiate educational programs to encourage aquaculture facilities to use only certified triploid bighead carp in all aquaculture applications. This initiative will provide a redundant measure to the risk of escape from properly sited aquaculture facilities.

**Recommendation 3.1.15.8. Encourage states to prohibit the use and production of silver carp on aquaculture facilities.**

Silver carp are not in commercial production, and regulations are warranted to prohibit their future use in commercial production.

**Recommendation 3.1.15.9. Encourage states to prohibit the use and production of diploid black carp on aquaculture facilities.**

State regulations to prohibit the use of diploid black carp are warranted. Black carp are not yet considered established within the United States. Black carp have the potential to survive almost anywhere in the United States where there is suitable habitat and food resources (Nico et al. 2005). Adult black carp have been collected from the wild; however, natural reproduction has not been documented through the collections of eggs and larvae or observations of spawning (Nico et al. 2005). Black carp have similar spawning requirements to grass carp and other Asian carps (Nico et al. 2005). Given that bighead, grass, and silver carps have established self-sustaining populations in large river within the Mississippi River Basin, it is reasonable to expect that feral black carp would be able to spawn successfully in these same large rivers and potentially establish self-sustaining populations (Nico et al. 2005).

**Recommendation 3.1.15.10. *UNRESOLVED ISSUE: Use of triploid black carp on aquaculture facilities.***

The Working Group was not able to reach consensus on recommendations regarding the use of black carp on aquaculture facilities. Working Group members agreed that the desired endpoint is to have no black carp in use on aquaculture facilities (or in the wild), but did not agree on how long it should take to reach this endpoint. The Working Group also agrees that research to identify feasible alternatives to black carp for snail control is the highest priority research need and that all stakeholders should be actively pursuing alternatives to black carp.

Some members of the Working Group support an approach that discourages the use of black carp, but until feasible alternatives are proven and available for snail control, certified triploid black carp (100% inspected/retested) would be permitted with appropriate controls for containment. The use of triploid black carp would require research to verify the functional sterility of black carp, a triploid inspection and certification program for black carp, and adequate and redundant controls for containment (see 3.1.15.1). Concurrent research for feasible alternatives to black carp for snail control is needed. However, there was disagreement on where triploid black carp should be permitted. Some members agreed that the limited use of triploid black carp should be restricted to the states and locations where black carp are currently produced or stocked (i.e., Arkansas, Mississippi, Missouri, and North Carolina), while others suggest that triploid black carp should remain an option to any aquaculture facility that encounters the need for snail control. There was also disagreement on how long triploid black carp should be allowed in the absence of feasible alternatives.

Other members of the Working Group oppose even limited use of triploid black carp because of the potential effects of individuals or reproducing populations of black carp on imperiled native mussels. These members support an approach that prohibits the use of black carp and the immediate application of all available resources at developing a solution to the problem of snail control, as opposed to validating a tool (i.e., triploid black carp) that may be a risk to imperiled mussels. To prevent the black carp from becoming established in rivers of the United States, temporary subsidies to farmers for losses due to inadequate snail control may be warranted.

The following questions remain to be resolved:

1) Should the use of triploid black carp for snail control on aquaculture facilities be:
    a. discouraged but permitted temporarily due to the absence of alternative methods of snail control, or
    b. be prohibited immediately?
2) If permitted temporarily, then should temporary use be allowed:
    a. indefinitely, until feasible alternatives to black carp for snail control are available, or
    b. for a limited time, only to a pre-determined date, regardless of the status of alternatives to black carp?
3) If permitted temporarily, then should the temporary use of triploid black carp be:
    a. restricted to the states and/or specific locations where permitted currently, or

b. allowed on facilities in any location based on need and state regulations?

<u>Background</u>
Aquaculture facilities have a critical need for effective control of snail-borne parasites (i.e., trematodes). The United States aquaculture industry is most concerned with several trematodes, particularly yellow grub, white grub, eye fluke, and one or more species of the genus *Bolbophorous*, that can adversely affect aquaculture production of several economically valuable food and bait fishes (Collins 1996; Venable et al. 2000; Terhune et al. 2002, 2003; Nico et al. 2005). In addition, a nonnative gill trematode that affects the health of both cultured and wild fish species, including endangered species, and its nonnative first intermediate host, the red-rim melania snail (*Melanoides tuberculatus*), are spreading in southern and western states (Mitchell et al. 2005). Since the mid-1990s, *Bolbophorous* trematode infestations have been of great concern to United State's channel catfish producers (Terhune et al. 2002).

The *Bolbophorous* trematodes have a complex life cycle involving one final host, the American white pelican (*Pelecanus erythrorhyncos*), and two intermediate hosts: ram's horn snails (*Planorbdella trivolvis*) and fish (Terhune et al. 2003). Evidence suggests that infection with this trematode is becoming widespread, with the more severely affected farms being in close proximity to pelican roosting or resting sites (Terhune et al. 2002; personal communication, David Wise, Thad Cochran National Warmwater Aquaculture Center). Channel catfish fry and fingerlings suffer high mortality rates and production of larger fish is reduced in severely affected production ponds (Terhune et al. 2002). Hanson and Wise (2005) estimated the net returns for channel catfish production ponds with relatively light infection of *Bolbophorous* trematodes were reduced by 80.8%, and production from ponds with more severe infection rates experienced net losses ranging on average from $1,251 to $1,560 per hectare. They further estimated the loss from *Bolbophorous* trematodes to producers in the main United States catfish-producing region as $45.4 million annually, more than 10% of the $450 million in catfish farm sales during 2004.

No U.S. Food and Drug Administration approved therapeutic treatment for fish infected with trematodes currently exists (Terhune et al. 2002, 2003; Ledford 2003). In the absence of therapeutic drugs, control of *Bolbophorous* trematodes is limited to preventing infestations by breaking the life cycle of the trematode. Breaking the life cycle requires controlling or eliminating the introduction of trematode eggs by pelicans, the trematode's free swimming life stages within production ponds, or ram's horn snails, the only known intermediate host for *Bolbophorous* trematodes (Kelly 2000; Ledford 2003; Terhune et al. 2003; Avery et al. 2004). Control of snail populations is the most practical option for breaking the parasite's life cycle (Ledford 2003; Terhune et al. 2003). Optimal control of snail populations requires a combination of biological, chemical, and mechanical controls (Ledford 2003; Avery et al. 2004). Removing vegetative growth in ponds and limiting the presence of pelicans near ponds are additional prophylactic measures for lessening infestations (Terhune et al. 2002).

Several chemical treatments provide effective control of snails in production ponds with limited affects on fish (Terhune et al. 2002). Hydrated lime, copper sulfate, and copper sulfate with citric acid can be effective in eliminating snails that live along pond margins, where most ram's horn snails are found (Venable et al. 2000). Bayluscide®, rock salt (NaCl), and copper sulfate can be effective options for treating whole ponds (Kelly 2000; Mitchell 2002; Ledford 2003; Mitchell and Hobbs 2003; Terhune et al. 2003; Avery et al.

2004; personal communication, David Wise, Thad Cochran National Warmwater Aquaculture Center). Available chemical treatments each offer unique benefits and limitations (Ledford 2003; Mitchell and Hobbs 2003; Terhune et al. 2003) that may preliminarily provide many producers (i.e., farms not in high-risk areas) with viable options for an integrated plan to control snails (personal communication, David Wise, Thad Cochran National Warmwater Aquaculture Center). However chemical treatments must be repeated for long-term snail control (Terhune et al. 2003) which increases costs to producers.

Biological control for the intermediate hosts of *Bolbophorus* trematodes offers a practical approach and may provide the best long-term control (Ledford 2003; Avery et al. 2004). Black carp, which feeds on snails, are an economical and effective tool for long-term biological control of snails (Slootweg et al. 1994; Shelton et al. 1995; Huckins 1997; Ledford 2003), especially in high risk areas where other means of snail control have been unsuccessful. In aquarium studies by Ledford (2003), black carp were the most effective consumers of ram's horn snails (mean=98%), irregardless of size of snail or water temperature. The effectiveness of black carp to control snails in aquaculture ponds is dependent upon stocking rates, level of snail infestation, species of snail to be controlled, and abundance of vegetation within ponds (Nico et al. 2005). Collins (1996) reported that it is difficult for black carp to control snails that burrow into the pond bottom and that snail control is greatly reduced by the amount of vegetation in the pond. Black carp have additional limitations such as eating channel catfish fry, reduced snail consumption when catfish feed is available, and potential environmental consequences due to the escape of a nonnative molluskivore (Ledford 2003).

There have been limited studies to date to evaluate the effectiveness of native molluskivores for the control of ram's horn snail in production ponds. In aquarium studies by Ledford (2003), redear sunfish consumed significantly less snails (mean = 38%) than black carp but were the most effective native species evaluated in the study. Ledford (2003) recommended redear sunfish for the biological control of ram's horn snail based on comparisons with other native species and the possible prohibition of black carp. However, redear sunfish would require more time to eliminate a snail population due to its inability to consume larger snails and the effect of lower water temperature on consumption (Ledford 2003). Additional native species could provide effective control of ram's horn snails, especially in combination with other control techniques, and warrant evaluation (Kelly 2000; Ledford 2003; Nico et al. 2005).

It is likely that no single method is the solution for snail control; rather different methods should be evaluated for use in conjunction with one another (Venable et al. 2000; Ledford 2003; Terhune et al. 2003; Avery et al. 2004). Several chemical and biological alternatives to the use of black carp for snail control in ponds have been studied (e.g., Venable et al. 2000; Mitchell 2002; Ledford 2003; Mitchell and Hobbs 2003; Terhune et al. 2003), but are less effective or present other limitations to their effective use. Black carp have limitations that also must be considered, such as eating channel catfish fry, significantly reduced snail consumption when catfish feed is available, and potential environmental consequences due to the escape of a nonnative molluskivore (Ledford 2003). Most catfish farms are located within Mississippi, Alabama, Louisiana, and Arkansas where there is a risk of escape of black carp due to a natural disaster (e.g., flood, tornado, or hurricane; Ledford 2003). The Southern Regional Aquaculture Center had an on-going, multi-state project related to *Bolbophorus* trematodes that included work on native species and chemical alternatives to snail control. From the results obtained with the limited species that were examined in that study, it is evident that additional research is needed to further evaluate alternative techniques for snail control. Consequently, the North Central Regional Aquaculture Center has issued a request for proposals to address possible methods of snail control using native fish species or a combination of native fish species and approved chemical controls for elimination of snail populations from commercial aquaculture ponds.

Beginning in the 1980's, private production facilities attempted to market black carp, primarily as a biological control agent for snails (Nico et al. 2005). Currently, triploid black carp are the only form of black carp sold within and between a very small number of states (i.e., Arkansas, Missouri, Mississippi, and North Carolina) as a biological control agent for nuisance snails (personal communication, Mike Freeze, Keo Fish Farm). However, the functional sterility of triploid black carp has not been evaluated, nor is there an established inspection and certification program for black carp.

If functionally sterile, the inability of triploid black carp to reproduce in the wild would greatly reduce the long-term effects of escaped black carp, but would not ameliorate the potential effects of non-reproducing fish on critically imperiled mussel fauna. Freshwater mussels are more diverse in eastern North America than any other continent in the world, yet more than half of the mussel species of the midwest are threatened or endangered (Cummings and Mayer 1992). "Black carp, whether introduced individuals or a reproducing population, could pose a serious threat to many of the remaining populations of endangered and threatened mollusks" (Nico et al. 2005). Nico et al. (2005) concluded that all size-classes of 12 (85%) of the 14 federally endangered unionid species in the midwestern United States are within the gape limits of a 2-meter long black carp.

In the two year period from March 2003 – April 2005, there were six verified collections of adult black carp in the Mississippi River Basin (Nico et al. 2005). Reports from commercial fishers indicate that black carp have been collected from parts of the Mississippi River Basin for more than 10 years (Nico et al. 2005). The reported and verified collections, including one fish that blood tests indicated was triploid (Nico et al. 2005), confirms the difficulty of containing black carp on aquaculture facilities. In contrast, triploid black carp are used on hybrid striped bass farms in North Carolina, but no black carp have been reported in the wild in the North Carolina (personal communication, Jeff Hinshaw, North Carolina Cooperative Extension Service).

***PATHWAY*: Incidental inclusion and potential release of Asian carps in "farm raised" baitfish**

***RISK LEVEL: Low Risk*** [17]

Bighead carps generally are not stocked in baitfish ponds, but black and grass carps are stocked in fathead minnow ponds for vegetation and snail control to prevent infestations of yellow grub. Yellow grub infestations in fathead minnow ponds have been reported to cause up to 80% mortality of fathead minnows (Mitchell 1995). Asian carps are not stocked in golden shiner (*Notemigonus crysoleucas*) or goldfish ponds because these fishes have delicate scales and are easily damaged by the larger Asian carps when harvested. In fathead minnow ponds in which black carp are stocked, the black carp are much larger and easily removed from nets if

[17] Pathway risk level ranking with which Working Group members expressed disagreement.

present during harvest. Because baitfish go through several days of intensive vat grading in sheds prior to sale, any black or grass carps present with fathead minnows should be identified and removed.

This pathway is indirectly addressed by Strategy 3.1.13. The Working Group did not identify additional Strategies or Recommendations specific to this pathway.

***PATHWAY*: Incidental inclusion of Asian carps in domestic shipments of food fishes**

***RISK LEVEL: Low Risk*** [18]

Bighead, black, and grass carps are stocked routinely into foodfish ponds with channel catfish, hybrid striped bass, and largemouth bass. Hybrid striped bass normally are packaged individually for sale; therefore, any incidentally included Asian carps should be removed during this process. Largemouth bass are often live-hauled to market; therefore, there is some risk of including Asian carps in these shipments. The primary foodfish industry in the United States is channel catfish. Bighead carp are co-cultured on some farms with channel catfish, and black carp are stocked in channel catfish foodfish ponds for snail control to prevent infestations of the non-native trematode (*Bolbophorus* spp.). Channel catfish raised as foodfish generally are sold to processing plants, most of which are located close to the production facilities. Processing plants must be permitted for discharge of wastes, and for this reason are not located near open bodies of water.

Black carp have no foodfish markets and must be removed from nets by hand when harvesting catfish, resulting in extra labor and additional costs (Venable et al. 2000; personal communication, Anita Kelly, Southern Illinois University). Black carp are very susceptible to catfish harvesting operations and seine crews must be diligent in returning black carp to the pond (Avery et al. 2004). However, due to the high growth rates of Asian carps, it is generally quite easy to distinguish these fish from the catfish due to their much larger size and different appearance. Because farmers are docked (reduction in price of fish) for non-target fish, there is an incentive for farmers to remove Asian carps before delivery to a processor. Asian carps that do arrive at a processing plant are electrocuted and sold dead to a rendering plant along with the rest of the waste products from processing.

This pathway is addressed by Strategy 3.1.13. The Working Group did not identify additional Strategies or Recommendations specific to this pathway.

***PATHWAY*: Incidental inclusion of Asian carps in domestic shipments of catfish to fish farms**

***RISK LEVEL: LOW RISK***

The Working Group considered the potential for Asian carps to be included incidentally in domestic shipments of catfish to other fish farms. The primary case would be that of catfish stockers (intermediate size ranging from 60-180 pounds/1000 fish) sold by one farm to another. These sales occur infrequently and, thus, are not part of the routine practices of catfish production. Some black and grass carps may be stocked into catfish fingerling ponds. Bighead carp are stocked in catfish foodfish grow-out ponds, not stocker or fingerling ponds. It is possible for black or grass carps to be loaded unintentionally onto a truck for delivery to another

[18] Pathway risk level ranking with which Working Group members expressed disagreement.

catfish farm. Black carp are very susceptible to catfish harvesting operations and seine crews must be diligent in returning black carp to the pond (Avery et al. 2004). The grower has an incentive to retain the black and grass carps in their ponds because if they are loaded out, the grower would lose the aquatic vegetation and snail control provided by these species and would incur additional expense for replacement. The much larger size of the Asian carps makes it relatively easy to remove them from a net of catfish stockers during the loading process. However, additional labor is required to remove black carp when harvesting catfish, which results in extra labor and additional costs to the farm (Venable et al. 2000; personal communication, Anita Kelly, Southern Illinois University).

This pathway is addressed by Strategy 3.1.13. The Working Group did not identify additional Strategies or Recommendations specific to this pathway.

## 7) *LIVE TRANSPORT*

***PATHWAY*: Domestic live transport and distribution of wild-caught fish**

***RISK LEVEL: Highest Risk***

Commercial fishers have an important role in the control and management of established populations of Asian carps (e.g., early detection and population control). However, commercial fishers also represent a potential pathway of accidental, or even deliberate unauthorized introductions. Commercial fishers in many locations throughout the Mississippi River Basin report high incidental catches of Asian carps, and a few commercial fishers who have access to markets target Asian carps (personal communication, Rob Maher, Illinois Department of Natural Resources). It is in the commercial fisher's financial interest to find markets for as much of a day's catch as possible, whether target or non-target fish. Asian carps harvested by commercial fishers are likely to be diploid fish. Transportation of these non-target fish to markets also entails a high risk of introduction into additional drainages and some risk of disease agent transfer. The potential clearly exists for commercial fishers to act as a vector of introduction if steps are not taken to ensure safe transport and handling of their catch. Regulations regarding the transport and sale of live wild-caught Asian carps are needed.

Although commercial fishers typically receive relatively low prices for Asian carps, higher prices can be obtained by selling them live in ethnic seafood markets. Ethnic seafood markets with a demand for live Asian carps are usually located in large cities (e.g., New York), requiring commercial fishers to transport their live catch away from the river of capture and often into watersheds without established populations of these fishes. In 2004, three live bighead carp that fell from a commercial fisher's boat were found along a state highway in Illinois (personal communication, Dan Sallee, Illinois Department of Natural Resources). In similar circumstances, fish may drop into waters along the highway or fall from a bridge into waters below. Passengers in other vehicles may stop to move fish to nearby waters; attempting with the best of intentions to rescue the fish, but potentially creating detrimental results. A vehicle accident could also provide a large-scale introduction into a waterway without an established population of Asian carps. The water used to transport live Asian carps also presents a threat of transferring Asian carp eggs or larvae (and other aquatic nuisance species) into new watersheds.

**Strategy 3.1.16. Take actions to prevent the live transport of wild-caught Asian carps and potential introduction through release, improper disposal, or escape.**

**Recommendation 3.1.16.1. Where legal for commercial or recreational fishers to possess Asian carps, encourage states to prohibit the possession of live wild-caught Asian carps.**

Encourage states to require all commercially- or recreationally-harvested Asian carps to be killed at the time of capture to prevent their live transport and potential introduction into new locations. States should prohibit the transport of live wild-caught Asian carps by commercial live haulers. Regulations are warranted to prevent the transport and distribution of live Asian carps away from the immediate waters in which the fish are collected. Even under closely managed transport, the distribution of live, primarily diploid, Asian carps into watersheds without established populations represents a substantial risk to the environment.

**Recommendation 3.1.16.2. Review Standard Operating Procedures and actions of commercial fishers to identify Best Management Practices that reduce risks of live transport and introduction.**

Natural resources management agencies should work directly with commercial fishers to review or establish Standard Operating Procedures involving wild-caught fish. Best Management Practices that reduce risks of introductions from live transport should be developed, shared, and encouraged throughout the industry. Trained managers should employ a Hazard Analysis and Critical Control Point planning approach to identify critical procedures, and work with commercial fishers to find solutions that minimize risks.

**Recommendation 3.1.16.3. Develop an information module and provide materials to commercial and recreational fishers and commercial live haulers that will help prevent accidental and deliberate unauthorized introductions of Asian carps.**

State natural resources management agencies license and regulate commercial and recreational fishers and should implement programs to directly communicate with the target audience and provide information on regulations regarding Asian carps and the reason that they exist. A number of informational materials have already been developed that convey information about Asian carps. Commercial and recreational fishers and commercial live haulers should be engaged to ensure that their specific education and outreach needs, and how to most effectively meet these needs, are understood. Interactions with the target audience and delivery of applicable existing information should begin immediately. Education and outreach will require a long-term sustained effort.

***PATHWAY*: Commercial, domestic transport of live farm-raised Asian carps**

***RISK LEVEL: Moderate Risk*** [19]

Bighead, black, and grass carps are traded commercially in the United States. The live transport of Asian carps to markets throughout the United States and into Canada is cause for concern because each shipment of live fish within a watershed without feral Asian carps creates the opportunity for introduction and establishment in new waters.

[19] Pathway risk level ranking with which Working Group members expressed disagreement.

The primary market for bighead carp is a live product sold in Asian ethnic markets in major cities in the United States and Canada. Bighead carp are transported live on specialized fish hauling trucks equipped with oxygen, a series of tanks, and generally on an 18-wheeled transport truck (Figure 3.1.1). The fish are off-loaded in wholesaler/distributor warehouses in the cities and then transported by smaller trucks to individual grocery stores for sales (Figure 3.1.2). Grass carp are transported in a similar manner, but are sold primarily for aquatic vegetation control, with some sales in the foodfish market. Black carp are sold for snail control for fish ponds in southern states. They are transported from hatcheries to fish ponds for stocking.

Asian carps can escape during commercial, domestic transport due to an accident or other human error. In nearly 25 years of livehauling, there has been only a single known report of an accident involving a truck while hauling live Asian carps. A tractor-trailer hauling 12,000 pounds of live bighead carp from Arkansas to an Asian fish food market in New York in 1996 overturned on Interstate 81 in Virginia (personal communication, Gary Martel, Virginia Department of Game and Inland Fisheries). The Fire Rescue Crew salvaged some fish by placing them in a local farm pond and requested permission to stock others into South Holston Lake. Although the likelihood of an introduction via this pathway is small, the risk to the environment is high in watersheds without established populations of these species.

In addition to the following strategies, this pathway is also addressed by Strategy 3.1.13.

**Figure 3.1.1.** Commercial hauling truck used to transport live bighead and grass carps from production facilities to food markets in the United States. Photo courtesy of David Heikes, University of Arkansas at Pine Bluff.

**Figure 3.1.2.** Warehouse delivery truck ready to unload live bighead at a fish market in New York City. Photo courtesy of David Heikes, University of Arkansas at Pine Bluff.

**Strategy 3.1.17. Take actions to prevent the release, escape, or improper disposal of domestic commercial shipments of live Asian carps.**

**Recommendation 3.1.17.1. Require informational labeling of truck and invoice for shipments of Asian carps to avoid improper handling and potential introduction of fish that may be involved in an accident (e.g., "Non-native fish: Unauthorized release prohibited").**

Labels on trucks hauling Asian carps and on the invoices would alert emergency personnel (e.g., police, fire, and rescue) and the public to the nature of the cargo. Such labeling may help avoid unauthorized human-mediated introduction of fish as occurred in the previously discussed incident. Labels must be supported by information programs so that highway patrol and emergency personnel know what to do.

**Recommendation 3.1.17.2. Review Standard Operating Procedures and develop Best Management Practices for fish haulers regarding containment and water transfer.**

A review of Standard Operating Procedures of livehaulers who transport Asian carps would provide a basis for determining operational areas for which Best Management Practices would be useful. Development of Best Management Practices should occur through a participatory process with the appropriate industry associations, university Cooperative Extension Service specialists, Sea Grant specialists, personnel associated with Regional Aquaculture Centers, and others, to ensure maximum compliance.

**Recommendation 3.1.17.3. Prohibit the use of water from natural water bodies for water exchange during transport.**
Livehaulers primarily use well water for transport and water exchange, if needed en route. However, the use of a natural water body for water exchange could introduce Asian carps into new locations and is suspected to be the source of bighead carp in South Holston Lake, Virginia (personal communication, Gary Martel, Virginia Department of Game and Inland Fisheries). Regulations are warranted to prevent introductions via this pathway.

**Recommendation 3.1.17.4. Investigate improvements for containment methods on trucks carrying Asian carps.**

Research into the possibility of improving the latch systems on livehauling trucks potentially could result in modifications that would prevent the lids of tanks from opening during an accident. Such modifications in the design would require thorough testing and evaluation, including field trials, to determine its feasibility both from a practical and an economic perspective.

**Recommendation 3.1.17.5. Develop an information module and provide materials to commercial transporters of live farm-raised Asian carps that will help prevent accidental and deliberate unauthorized introductions.**

Little information is available concerning factors that may contribute to accidental release or escape during transport. Stakeholders representing a cross section of interests should work directly with commercial transporters of live Asian carps to review and understand their Standard Operating Procedures, as well as, their specific education and outreach needs. Meeting these needs will result in a reduced risk of escape during transport. Transporters are not limited to commercial livehaulers, and may also include fish farmers, wholesalers, live haulers, fish retailers, consumers, and researchers.

University aquaculture Cooperative Extension educators, trade publications, trade associations and the media have informed some transporters about the potential risks associated with their business. Some university aquaculture Cooperative Extension educators and trade associations have also provided information to improve transportation practices.

**Strategy 3.1.18. Reduce the potential risk to the environment from continued commercial, domestic transport of live farm-raised Asian carps.**

The following recommendation addresses only bighead and grass carps. If Recommendation 3.1.15.8 ('Encourage states to prohibit the use and production of silver carp on aquaculture facilities') is adopted there will be no need to take further actions to prohibit commercial, domestic transport of live farm-raised silver carp. Likewise, the Working Group did not develop recommendations addressing the commercial, domestic transport of live farm-raised black carp, pending decisions on Recommendation 3.1.15.10: Use of triploid black carp on aquaculture facilities. The transport of live farm-raised black carps currently is limited to movements within and between a very small number of states (i.e., Arkansas, Missouri, Mississippi, and North Carolina) as a biological control agent for nuisance snails (personal communication, Mike Freeze, Keo Fish Farm).

**Recommendation 3.1.18.1. *UNRESOLVED ISSUE: Commercial, domestic transport of live farm-raised bighead and grass carps.***

The Working Group was not able to reach consensus on recommendations regarding all aspects of commercial, domestic transport of live farm-raised bighead and grass carps. Working Group members agreed that any commercial transport of live fish should be conducted with adequate controls to prevent escapes (Strategy 3.1.17) and with the requirement that all fish are killed at the point of sale, with the exception of authorized stockings of grass carp to control nuisance aquatic vegetation. As with other pathways, recommendations to address live transport were considered based on whether or not bighead and grass carps are absent, present without evidence of natural reproduction, or are self-sustaining in the wild. However, the Working Group did not agree on the specifics of live transport of these fishes as outlined in the questions below.

Watersheds where bighead and/or grass carps are self-sustaining in the wild:
Working Group members agreed that commercial live transport of bighead and grass carps is acceptable within watersheds where these species are self-sustaining in the wild. However, the Working Group did not agree on whether or not live transport within these watersheds should be limited to certified triploid fish only or if diploid fish should be permitted.

The following question remains to be resolved:

1) Should the live transport of bighead and grass carps in watersheds where bighead and/or grass carps are self-sustaining in the wild be:
   a. limited to certified triploids only, or
   b. allowed for diploids, given the use of adequate controls to prevent escape and the requirement that the fish are killed at the point of sale?

Watersheds where bighead and/or grass carps are absent or are not self-sustaining in the wild:
Some Working Group members suggested that to prevent introductions or range expansions of these species, commercial live transport should be prohibited within any watershed where bighead and grass carps are not self-sustaining. Some members support prohibiting commercial live transport where the fish are completely absent in the wild, but allowing certified triploids to be live-hauled within watersheds where the fish are present but not self-sustaining. Other members support commercial live transport of certified triploids within watersheds where the fish are completely absent in the wild.

Some members suggested that the commercial live transport of diploid bighead and grass carps should be permitted within any watershed.

The following questions remain to be resolved:

1) Should the live transport of bighead and grass carps in watersheds where bighead and/or grass carps are absent in the wild be:
   a. prohibited, or
   b. allowed for certified triploids only, given the use of adequate controls to prevent escape and the requirement that the fish are killed at the point of sale, or
   c. allowed for diploids, given the use of adequate controls to prevent escape and the requirement that the fish are killed at the point of sale?

2) Should the live transport of bighead and grass carps in watersheds where bighead and/or grass carps are present but not self-sustaining in the wild be:
   a. prohibited, or
   b. allowed for certified triploids only, given the use of adequate controls to prevent escape and the requirement that the fish are killed at the point of sale, or
   c. allowed for diploids, given the use of adequate controls to prevent escape and the requirement that the fish are killed at the point of sale?

<u>Background</u>

Most live foodfish markets for bighead and grass carp are located outside the range of self-sustaining populations of these species in the wild. High volumes of bighead and grass carps generally are transported by commercial live haulers and a single accident could potentially introduce large numbers of these fish into new waters. Additional or improved containment measures to prevent escape during commercial transport may further reduce the probability of escapes (Recommendation 3.1.17.4). Studies of live transport have been suggested to provide an understanding of the frequency that accidents and potential introductions might be expected to occur. However, it is generally accepted that the probability of an accident occurring is low. What is not generally accepted is whether the low probability of an accident occurring and the potential introduction of large numbers of bighead or grass carp into a new watershed is a substantial enough risk to the environment to warrant management actions that would likely have an economic impact on some stakeholders.

Restricting commercial transport of live bighead and grass carps to certified triploids only would reduce the risk to the environment in the event of an introduction. However, the economic effect of requiring the aquaculture industry to produce only triploids for foodfish sales is not understood. Tave (1993) reported that triploid bighead carp grew more slowly than diploid bighead carp. There have been anecdotal reports of slower growth of triploid grass carp when compared to diploid grass carp. Slower growth results in lower yields (kg/ha/yr). Lower yields increase annual fixed costs and annual total costs per unit of production (Shang 1990; Jolly and Clonts 1993; Engle and Hanson 2004). Thus, higher production costs due to the slower growth and higher fingerlings cost will reduce gross returns. Markets may not support the higher production costs being past on to consumer as higher retail prices. Research is needed to evaluate the extent of the losses to producers and to evaluate whether switching exclusively to triploid bighead and grass carp production for the foodfish market is economically feasible. Indemnification programs to compensate farmers for the losses may be warranted.

# 8) ***ACCIDENTAL AND DELIBERATE UNAUTHORIZED RELEASES BY INDIVIDUALS***

***PATHWAY*: Accidental and deliberate unauthorized release by individuals**

***RISK LEVEL: Highest Risk*** [20]

There are several potential sources of accidental and deliberate unauthorized release, escape, or improper disposal of Asian carps into open waters of the United States. One pathway is cultural, ceremonial, or symbolic releases related to special events. It has been a long tradition in some Southeast Asian cultures to release fish as a way to recognize very special events (e.g., birth of child, funerals, or New Year celebrations). There are most likely two levels of this practice in the United States. One is the release of small, easy to obtain fish, from pet or bait stores, into small ponds at temples for ceremonial reasons. This does not appear to be a likely pathway for Asian carp introductions. A second pathway is catching and subsequently releasing wild-caught fish. It is a cultural practice among some religious groups to release fish as a symbolic token. This generally occurs with wild-caught fish and not with fish purchased live at a fish market. However, fish markets could provide a source for live Asian carps in locations where they are not present in the wild. While releases are usually done infrequently by an individual or individual family (every 5-15 years; personal communication, Josee Chung, Minnesota Department of Natural Resources), the cumulative effect of many individual actions over time elevates the risks associated with this pathway.

Another potential pathway is the retail sale of live Asian carps as food fish. Many retail grocers within ethnic communities have specialized market sales of live Asian carps. Consumers within these markets prefer to purchase live Asian carps rather than dead or even freshly killed fish (Kerr et al. 2005). The sale of live fish within these markets has created considerable concern over potential unauthorized introduction; enough concern that some large cities have promulgated local laws that require Asian carps sold live by a retail grocer to be slaughtered upon sale (Higbee and Glassner-Shwayder 2004). California does not allow most species of live Asian carps within its borders and all fish market sales are limited to dead product. Any of these fish that are transported live to the state line must be killed before entering the state (personal communication, Bob Hulbrock, California Department of Game and Fish).

Release and/or improper disposal of aquaria or hobby fish are additional pathways for the unauthorized introduction of Asian carps and other nonnative fishes (see www.habitatitude.net/). Although uncommon in the aquarium/hobby industry, bighead carp have been advertised for sale by hobbyists on the Internet (e.g., www.aquabid.com). Internet trade by aquaria owners and hobbyists is a possible, but unlikely pathway for the introduction of Asian carps. However this pathway provides for the potential introduction of Asian carps anywhere in the United States. The extent of this pathway is unknown.

**Strategy 3.1.19. Take actions to prevent the accidental and deliberate unauthorized release of Asian carps by individuals.**

> **Recommendation 3.1.19.1. Encourage states to prohibit the sale, live transport, and unauthorized release of live Asian carps for non-commercial uses.**

[20] Pathway risk level ranking with which Working Group members expressed disagreement.

States should be urged to develop specific regulations that prohibit sales of live Asian carps, live transport, and unauthorized release by private individuals. Regulations are needed to address sales by private individuals, especially via the Internet.

**Recommendation 3.1.19.2. Encourage states that allow sales of live Asian carps for human consumption to require retail grocers to kill the fish using prescribed humane methods, immediately upon sale.**

Live fish must not be permitted out of the possession of the retailer. Retail grocer associations should be involved in discussions related to the most effective means of preventing escape of live fish.

**Recommendation 3.1.19.3. Use educational campaigns such as Habitattitude$_{TM}$ to convey messages to the public that they should not release live Asian carps.**

Information may be as powerful as regulations in the effective control of this pathway. Effective informational programs directed at the appropriate audiences are needed. Information awareness campaigns that focus on segments of the public most likely to transport live Asian carps and accidentally or deliberately release fish should be developed immediately.

**Recommendation 3.1.19.4. Develop an information module and provide materials to producers, growers, marketers, and foodfish consumers of live Asian carps that will help prevent accidental and deliberate unauthorized introductions.**

Stakeholders representing a cross section of interests should work directly with producers, growers, marketers, and foodfish consumers of live Asian carps to understand their operational functions and specific education and outreach needs, as well as how to most effectively meet these needs to result in a reduced risk of accidental and deliberate unauthorized releases by this group.

Developing a complete functional list of producers, growers, marketers, and foodfish consumers of live Asian carps is not feasible because of the diversity of groups and operations. Identifying effective outreach methods to improve operational practices or behaviors to reduce the risks of accidental and deliberate unauthorized introductions of Asian carps will be challenging. Language differences may require the need for both verbal and written translations.

## 9) ***AQUARIUM / HOBBY INDUSTRY***

***PATHWAY*: Aquarium/hobby industry**

***RISK LEVEL: Moderate Risk*** [21]

Millions of live fishes are imported, sold, and shipped throughout the United States for the aquarium and hobby industry each year. The Working Group recognized aquarium hobbyists, backyard pond owners, and water gardeners as the end consumers for the aquarium and hobby industry. Release, escape, and improper disposal of Asian carps by various consumers are

[21] Pathway risk level ranking with which Working Group members expressed disagreement.

addressed under “accidental and deliberate unauthorized releases by individuals”. This pathway specifically addresses the commercial suppliers of aquarium/hobby industry fishes.

Various species of carp dominate world finfish aquaculture, representing more than 90% of all finfish aquaculture harvests (Shivappa et al. 2004), however there is little or no current interest for Asian carps within the aquarium/hobby industry. Koi and goldfish are both non-native Cyprinids important to the United States ornamental fish industry (Shivappa et al. 2004), but are not included in the collective term of “Asian carps” in this document. Asian carps generally are not used within the aquarium hobby industry and are, therefore, considered a possible, but unlikely pathway.

Fish sold in the aquarium/hobby industry originate from farms in the United States or are imported from international suppliers. The volume of live fish in trade in the aquarium/hobby industry poses a risk of introduction. Inclusion of Asian carps with aquarium and hobby fish, including Koi carp, is considered unlikely. Aquaria fish are typically sorted, held, and sold by species; therefore, mixing of species is not economical and measures are taken to avoid mixing species in shipments. Even if co-mingled in shipments, wholesalers and retailers hold fish in closed systems that are subject to effluent discharge regulations and to inspection by the USFWS. Larger Asian carps should be easily distinguished by size during sorting or holding. Individual Koi carp can have a potential market value of tens of thousands of dollars (Shivappa et al. 2004) and are typically hand selected, tank sorted, and held in higher water quality conditions (personal communication, Marshal Myers, Pet Industry Joint Advisory Council). Mixing of Asian carps in shipments of Koi carp is, therefore, unlikely.

**Strategy 3.1.20. Take actions to prevent the release, escape, or improper disposal of Asian carps by aquarium/hobby industry importers, wholesalers, and retailers.**

> **Recommendation 3.1.20.1. Encourage states to prohibit the trade of Asian carps for aquaria and hobby purposes.**
>
> Currently there is no known trade of Asian carps in the aquarium/hobby industry. State regulations that prohibit the import and trade of Asian carps for aquaria and hobby purposes are needed to prevent such trade from occurring in the future. This recommendation should have no adverse effects on the aquarium/hobby industry and is an effective, proactive control for a potential pathway of introduction.

## 10) ***<u>RESEARCH AND EDUCATIONAL FACILITIES</u>***

***PATHWAY*: Research and educational facilities and projects**

***RISK LEVEL: Moderate Risk*** [22]

Three separate levels of educational and research facilities were identified within this pathway. Research projects by government or university researchers; less formal educational projects at high schools, junior highs, or elementary schools; and routine operations of public aquaria are all potential sources for accidental or deliberate unauthorized releases, escapes, and improper disposal of Asian carps.

[22] Pathway risk level ranking with which Working Group members expressed disagreement.

Unplanned introductions from government and university level projects and public aquaria are possible, but unlikely. Typically those participating in these projects establish and follow protocols for research projects that include methods for appropriate disposal (e.g., animal care and handling protocols). The *Guidelines for the Use of Fishes in Research* provides "a structure that ensures appropriate attention to valid experimental design and procedures" for general use by researchers in the United States (Nickum et al. 2004). An Aquatic Nuisance Species Task Force Research Committee will review and update a research protocol that provides guidance for federally funded research involving aquatic nuisance species. Federally funded research must meet National Environmental Policy Act requirements and this is part of all intramural federal research programs as well.

Lower level education and research projects are also a potential pathway for unauthorized introductions of Asian carps. This is because facilities may not have adequate containment and students and teachers may not be aware of protocols, permit requirements, or other precautions to avoid actions that could lead to introductions of Asian carps into new waters. Often, students are enthusiastic about helping science by conducting simple science projects with nuisance species that are in the news. It is not unreasonable to expect that students will try to obtain nuisance species such as Asian carps for school projects. If they obtain these fishes, it is probable that some students will not want to euthanize the fish, but will make plans to release them.

**Strategy 3.1.21. Prevent the release, escape, or improper disposal of live Asian carps via education facilities and projects, including schools, public aquaria, and research facilities.**

**Recommendation 3.1.21.1. Urge states to develop and enforce regulations to reduce risks associated with the possession and disposal of Asian carps for research and exhibition purposes.**

Encourage states to develop regulations restricting the possession and disposal of Asian carps for research and exhibition purposes. Research and exhibition facilities should be required to provide reasonable and effective protocols to prevent the release, escape, or improper disposal of Asian carps before permission to possess the fish is granted.

**Recommendation 3.1.21.2. Develop an information module and provide materials to the academic and research communities that will help prevent accidental and deliberate unauthorized introductions of Asian carps.**

Stakeholders representing a cross section of interests should work directly with the academia and research communities to understand their operational functions and specific education and outreach needs, as well as how to most effectively meet these needs to result in a reduced risk of accidental and deliberate unauthorized releases by this group.

## 11) ***RECREATIONAL BOATERS AND FISHERS***

***PATHWAY*: Intentional release of live, "adult-sized" (non-baitfish) Asian carps by boaters, anglers, and bow fishers**

***RISK LEVEL: Low Risk***

The release of live, "adult sized" Asian carps by boaters, anglers, and bow fishers is considered a low risk pathway. Boaters are unlikely to come into contact with bighead, black, or grass carps. Silver carp will jump into boats creating a potential pathway of introduction that should be addressed. However, boaters are not likely to possess large numbers of silver carp or transfer these fish to different waters. Bowfishers capture many Asian carps, but any fish in the possession of a bowfisher are likely to have been captured after being speared by an arrow. There seems little risk of bowfishers transferring live Asian carps between waters. Recreational anglers are likely to catch an occasional bighead or silver carp. Grass carp are targeted by some recreational fishers. Recreational anglers are not likely to possess large numbers of Asian carps, but do present a potential pathway that should be addressed.

**Strategy 3.1.22. Take action to prevent the transport and release of adult sized (non-baitfish) Asian carps by boaters, anglers, and bowfishers.**

**Recommendation 3.1.22.1. Develop an information module and provide materials to recreational fishers and boaters that will help prevent accidental and deliberate unauthorized introductions of Asian carps.**

An information module and outreach materials are needed to reduce the risk of accidental or deliberate unauthorized releases of Asian carps by recreational fishers and boaters. It is critical that these groups understand how and why to help prevent introductions. Stakeholders representing a cross section of interests should work directly with the recreational fishers and boaters to understand their specific education and outreach needs, and how to most effectively meet these needs to reduce risk of accidental and deliberate unauthorized releases by these groups.

Numerous Asian carp outreach events of a general nature occur regularly across the geographical range of established Asian carp populations in the United States. Current outreach activities include WATCH cards and poster displays. Messages targeting recreational boaters and fishers should be included in state and federal boating and fishing materials and websites. Information about Asian carps should be included in the Stop Aquatic Hitchhikers! Campaign, materials posted at tackle shops, boat ramps, and marinas; and included in outdoor publications and television programs.

# Goal 3.2. Contain and control the expansion of feral populations of bighead, black, grass, and silver carps in the United States.

Feral bighead, black, silver, and grass carps are spreading by larval dispersion and/or migration throughout the Mississippi River Basin and threaten to expand to additional watersheds via interbasin connections (e.g., canals and waterways) and human-mediated spread. To prevent their expansion into waters where they do not exist, a long term, dedicated, and cooperative effort by federal, state, tribal and private partners is required to create or maintain dispersal barriers and to develop forecasting, detection, and rapid response capabilities to control or eradicate new populations. Targeted reductions in the abundance of feral Asian carp populations (Goal 3.3), especially at the periphery of the range and near dispersal barriers, will improve efforts to contain and control the expansion of feral Asian carps by lowering the chance that these fish will invade or establish in new areas. Containment and control capabilities exist in a limited number of local jurisdictions (e.g., Chicago Sanitary and Ship Canal), but have not been widely developed on a national scale. Nationally coordinated capabilities and actions are likely to require a dedication of resources and manpower akin to those established for wildfire management and suppression.

**Strategy 3.2.1. Develop a national strategy and guidelines for science-based decision making concerning the need for continued and additional containment measures.**

The rapidly growing and expanding populations of bighead and silver carps are forcing federal and state agencies to develop both immediate and long-term strategies for containing these fishes and for limiting their distribution. Decisions to undertake specific containment actions should be science-based. In addition, a long-term strategic, rather than an opportunistic, approach should be used to contain feral Asian carps. Due consideration should be given to the effects of containment actions on the long-term ecological sustainability of native aquatic resources.

**Recommendation 3.2.1.1. Develop a Decision Support System to assist natural resources managers in prioritizing specific locations for the construction, maintenance, monitoring, or removal of barriers to carp dispersal.**

A Decision Support System based on computer models developed using reliable data is the best approach to synthesize the available information and allow for informed decision making. Specifically, a Decision Support System would be used to

- describe and understand the current distribution of feral carps
- estimate the future rate of spread, establishment, and consequences of Asian carps in the absence of actions to contain feral populations
- estimate the effects of limiting the distribution and connectivity to habitats of native species as a result of implementing containment actions
- evaluate the effectiveness and need for existing dispersal barriers
- estimate the dispersal of Asian carps and effects on native communities upon removal or bypass of existing barriers (i.e., fish passage)
- identify high risk areas and waters of special concern
- prioritize specific locations for the construction, maintenance, monitoring, or removal of barriers to Asian carp dispersal.

The Decision Support System should be a collaborative project with national participation in the design of the tool, analysis of the data, and development of recommendations.

The Decision Support System will provide the scientific basis to develop a national strategy for actions to contain feral populations. Natural resources management agencies will more effectively contain Asian carps, use limited resources, and obtain new funds by working together under a national strategy. The timeframe for developing a Decision Support System is dependant upon factors such as research capabilities, agency collaboration, and funding. Depending upon the funding and staffing committed to the completion of the project, a fully functional Decision Support System could take from one to several years to develop. However, containment measures are needed now to be most effective; therefore, a preliminary model based on the expert opinions of a diverse group of scientist and managers should be developed and implemented as soon as possible. Models based on expert opinion have proven to be highly functional in many other situations. Never-the-less a complete Decision Support System is warranted and will provide a more accurate and predictable basis for sound decision making in the future and would set up a management framework for other aquatic nuisance species introductions. It is reasonable to expect that management questions involving actions to construct, maintain, monitor, or remove water control structures, or other potential barriers to Asian carp dispersal, will need to be addressed well beyond the timeframe required to develop a Decision Support System. In addition, many of the Geographic Information System coverages that are needed for the Asian carp Decision Support System could be used to evaluate and address introductions of new aquatic nuisance species in the future.

**Recommendation 3.2.1.2. Evaluate the effectiveness afforded by alternative technical containment measures (i.e., physical and behavioral barriers).**

Potential barrier and deterrent systems that may limit the movement and establishment of Asian carps are summarized in Appendix 6.3. There are two barrier and deterrent classifications presented; behavioral and physical. Behavioral guidance technologies include methods that employ sensory stimuli that cause migrating fish to avoid, or move away from, specific areas. The purpose is to discourage fish from entering a particular area and to make it desirable and possible for them to move elsewhere. Examples include strobe lights, air bubble curtains, acoustic deterrents, electrical disbursal barriers, hydrodynamic louver screens, and combination systems that may use two or more systems to provide a more effective barrier or deterrent. Physical barriers have been used in numerous locations to prevent fish movement through the use of rotating drum screens, traveling screens, floating curtains, vertical drops (existing and constructed), and velocity barriers.

The available data on the effectiveness of deterrents for Asian carps should be compiled, their biological and practical effectiveness on Asian carps and native fishes analyzed, and the circumstances under which each deterrent is most effective evaluated. Field tests should be conducted for barriers that are deemed likely to be effective. Further research is needed to explore other innovative methods as alternatives to effectively contain feral Asian carp populations.

**Recommendation 3.2.1.3. Promote, support, and provide technical analysis and comment for the field testing of novel containment methods.**

Effective containment is an immediate need that will require a long term commitment of personnel, equipment and funding. Publication of this national management and control plan and on-going research and development efforts should yield innovative methods to contain Asian carp range expansion. Field testing should begin immediately to test and refine technologies while the Decision Support System is being developed. Preference should be given to technologies that may be selective and allow native fishes to pass while deterring passage of Asian carps. Personnel, equipment, and funds must be made available to field test ideas, promote technology transfer, select appropriate riverine sites, and develop and monitor performance measures.

**Recommendation 3.2.1.4. Anticipate and address consequences of specific containment actions on native biological communities.**

Natural resources managers must consider the entirety of effects that may be brought about by specific containment actions. In addition to the intended effects on Asian carps, planning, design, and evaluation of containment measures must anticipate and address the probable consequences to native communities. Planners must do their best to determine if the costs of containment actions are too great for the future sustainability and health of native aquatic resources before projects are implemented. Containment actions implemented without due consideration of the consequences to native communities may do more harm than good. Barriers may be used as temporary measures that can be removed in the future; however the establishment of Asian carps in new waters is likely to be permanent and have irreversible effects on native communities. Information on native aquatic communities and habitats should be included in the development of decision support tools, and assist the formation of a national strategy to identify and prioritize needed containment measures (Strategy 3.2.1).

**Strategy 3.2.2. Take immediate actions to prevent interbasin transfers and limit intrabasin movements of feral Asian carps populations.**

Once an aquatic nuisance species becomes established it can be very difficult and costly to manage and potentially impossible to eliminate (Kolar et al. 2005; USEPA 2005). The best protection for native aquatic ecosystems is to minimize the distribution of feral Asian carp populations and prevent their access to additional waters. Immediate actions are warranted to prevent the expansion of feral Asian carp populations throughout the Mississippi River Basin and into new watersheds. Navigation locks and dam systems have slowed but not stopped the upriver migration of these fishes. Canals and waterways have been constructed throughout the country to facilitate the transfer of waters, people, and commodities between basins. These same interbasin connections now threaten to facilitate the dispersal and range expansion of Asian carps.

**Recommendation 3.2.2.1. Develop and implement redundant barrier systems within the Chicago Sanitary and Ship Canal to limit the unrestricted access of Asian carps to Lake Michigan.**

Natural resources managers are concerned about the potential introduction of Asian carps into the Great Lakes. Bighead carp have been collected from the Illinois River within 50 miles of Lake Michigan. The Chicago Sanitary and Ship Canal (Appendix 6.4), is the primary key to stopping large numbers of these nuisance fishes from dispersing into Lake Michigan and the other Great Lakes. An initial dispersal barrier (Barrier I) was constructed on the Chicago Sanitary and Ship Canal near Romeoville, Illinois, as a demonstration project. The barrier was activated in April of 2002 and has an expected service life of three to five years. It is intended to deter fish movements in the canal by repelling them with electroshock. The electric charge (2-3 volts per second per in$^3$) is not considered lethal or even injurious to humans, mammals, or fish. The manufacturer (Smith-Root Inc, Vancouver, Washington) estimates the barrier's efficiency in the mid 80% range (Moy 1997), and has stated a need for two or three more such barriers downstream to gain 100% efficiency. Cost of the structure was approximately $2.2 million (USEPA 2006). There is interest in maintaining Barrier I as part of an overall barrier project. Continued operation of Barrier I will require the installation of new, heavier electrodes at an estimated cost of $5.5 million (University of Wisconsin Sea Grant Institute 2006).

Construction of a second, larger, and more powerful barrier (Barrier II) is being completed in two phases. The first half of Barrier II (IIA) is expected to go online in January, 2006 and the second portion of Barrier II (IIB) will be completed in late spring or early summer 2006 (University of Wisconsin Sea Grant Institute 2006). Design of this barrier incorporated results of research conducted with bighead and silver carps in a laboratory setting. The barrier will be more effective on small fish and will have dual arrays to prevent passage of large fish in association with barge traffic. Without federal legislation, responsibility for operation and maintenance of Barrier II will be transferred to the State of Illinois. Estimated cost for full operation and maintenance of Barrier II is estimated at $450,000 per year ($37,500 per month; personal communication, Steve Shults, Illinois Department of Natural Resources). Legislation has been introduced (Water Resource Development Act of 2005, H.R. 2864) that would (1) fund improvements to Barrier I to make it "permanent", (2) provide full federal funding for the operation and maintenance of Barrier II, and (3) reimburse the eight Great Lakes states that contributed the non-federal funds for construction of Barrier II.

In addition to the Chicago and Sanitary Ship Canal electrical barriers, the feasibility of additional electrical barriers for construction within the Des Plaines River needs to be investigated. Other technologies such as the creation of a 3-5 mile anaerobic zone in the canal should be investigated, as should the construction of a physical dam or levee to separate the two ecosystems.

The Proceedings of an Aquatic Invasive Species Summit hosted in Chicago during 2003 (City of Chicago and USFWS 2003) identified three general approaches for preventing the exchange of aquatic invasive species between the Mississippi River and Great Lakes basins. These approaches include 1) investigate and evaluate hydrologic separation of the two basins; 2) pursue additional control and prevention technologies; and 3) procure broad-based political support and federal funding for developing and implementing solutions. The recommendations from the Chicago Summit should be considered during the planning, development, and implementation of water resources projects in the Chicago area.

**Recommendation 3.2.2.2. Develop and implement reasonable and effective measures that prevent the spread of Asian carps via canals, water ways, or other water diversions between basins.**

Canals and waterways have been constructed throughout the country to connect basins and facilitate the transfer of waters, people, and commodities between basins. Actions are needed to close open hydrologic connections in non-commercial canals with physical barriers or control structures and investigate the feasibility and effectiveness of alternative barriers in canals and waterways with commercial navigation. In addition to the Chicago Sanitary and Ship Canal, the Great Lakes Regional Collaboration Aquatic Invasives Species Strategy Team Action Plan (USEPA 2005) identifies the Ohio canals and waterways system as priority interbasin connections that must be addressed to prevent the spread of Asian carps into the Great Lakes. Particular attention should be directed to the Ohio and Erie and Miami and Erie canals. The potential for spread of Asian carps from the Ohio River Basin into the Great Lakes via these routes is significant. Efforts to improve recreational access must consider effective means to prevent the spread of Asian carps.

Efforts are needed to identify locations where intermittent flood-related connections occur between watersheds and take reasonable and effective actions to prevent the transfer of Asian carps and other aquatic nuisance species via these connections. This is particularly important where natural waterways may parallel canals, as occurs in the Chicago region. The Des Plaines River and Deep Run Creek parallel the Chicago Sanitary and Ship Canal for several miles. To ensure the effectiveness of the existing electric barrier, flood-related connections between these waterways must be eliminated.

Water resources development and other projects have been constructed that transfer waters between basins and warrant careful evaluation for their potential to expand the range of Asian carps and other aquatic nuisance species. Water transfer projects within the range of feral Asian carp populations can expand feral populations if viable eggs, larvae, or fish are transferred in project waters. Existing canals, water ways, and water transfer projects should be evaluated for their potential to transfer Asian carps and other aquatic nuisance species. Reasonable and effective measures should be implemented to reduce associated risks. Similar consideration should also be made for all future water transfer projects to provide reasonable and effective assurances that these projects will not expand feral populations of Asian carps or other aquatic nuisance species.

**Recommendation 3.2.2.3. Construct and operate a Sound Projector Array-based acoustic bubble curtain fish deterrent at two locks and dams on the Upper Mississippi River to prevent the spread of Asian carps throughout the basin.**

Fish deterrents must be constructed and activated quickly to limit the range expansion of Asian carps in the Upper Mississippi River Basin. A study, funded by the states of Minnesota and Wisconsin and the USFWS, was conducted by a consulting firm to evaluate the feasibility of installing existing and new technologies for “stopping the northward movement” of Asian carps in the Upper Mississippi River (FishPro 2004). The study’s final report ranked sound projector array-based, acoustic bubble curtains downstream of locks and dams as the most feasible and potentially most effective barrier to slow the spread of feral populations of Asian carps from their existing ranges. (See Appendix 6.5 for an overview of acoustic technology.)

The USACE is authorized to construct and maintain locks and dams in the Upper Mississippi River and Illinois Waterway. If authorized, and funded, the USACE would lead the project to design, plan, and install these fish deterrents as a demonstration project. The recommended technologies have not been tested in rivers the size of the Mississippi River. Demonstration projects are operated for relatively short periods of time (less than 3-years) to test new technologies. Once they are tested, they are decommissioned. Additional authorization and appropriation would be required to install, operate and maintain permanent deterrent systems. Responsibility for operation and maintenance of these systems could fall upon other federal agencies or on the non-federal project sponsor.

**Recommendation 3.2.2.4. Identify additional containment measures needed to limit intrabasin movements of feral populations of Asian carps within the Mississippi River and other basins where established.**

The best protection to native ecosystems is to prevent the establishment of Asian carps. In those waters with populations, containment can prevent or slow their distribution throughout a system.

Using available information, natural resources managers should determine current distributions of Asian carps within their jurisdictions, and predict where expansion is likely to continue in the absence of actions to contain them. Natural resources management agencies should also identify waters of special concern, for example

- waters containing populations of endangered and threatened mollusks that may be threatened by feral populations of black carp;
- waters with unusual or sensitive biodiversity that would be affected by feral populations of Asian carps; and
- waters of economic importance would be affected by reduced stocks of sport fish and the presence of silver carp.

Natural resources managers must weigh the economic costs of individual actions against the anticipated economic and ecological benefits.

As discussed in Strategy 3.2.1, natural resources managers should work together to develop and operate within a national strategy to address the containment of feral populations where appropriate. Partner agencies should begin working together immediately to pool information and resources to effectively address this issue.

**Strategy 3.2.3. Minimize the range expansion and ecological effects of feral populations of Asian carps in conjunction with management actions to enhance aquatic environments for the sustainability of native biological communities.**

Natural resources management agencies and institutions are investing millions of dollars and thousands of hours enhance aquatic environments to sustain native communities. Restoring habitat connectivity, has come under question because of the continual invasion of aquatic nuisance species, especially Asian carps. Expanding the range or increasing the abundance of Asian carp populations can be unintended effects of these actions. Natural resources managers must weigh the benefits that habitat enhancements will have on Asian carps and other non-native organisms, as well as to the native communities that they are intended to help sustain. In the end, natural resources managers must decide if the native biological communities are more sustainable with or without specific projects to enhance the aquatic environment.

**Recommendation 3.2.3.1. The USFWS and other natural resources management agencies should provide technical assistance and biological information to the USACE and participate in collaborative planning of fish passage structures at Lock and Dams.**

The USACE plans to construct fish passageways at the following locations by 2020 as part of the Navigation and Ecosystem Sustainability Program:

- Lock and Dam 26 at Alton, Illinois
- Lock and Dam 22 near Saverton, Missouri
- Lock and Dam 8 at Guttenberg, Iowa
- Lock and Dam 4 near Wabasha, Minnesota.

The USACE will also complete engineering and design for fish passage at Lock and Dam 19 at Keokuk, Iowa by 2020. Evaluations of fish passage alternatives must consider potential benefits to Asian carps and other nonnative species (i.e., range expansion), as well as adverse effects on the sustainability of native aquatic communities and habitats.

The USACE is developing these projects in collaboration with federal and state natural resources management agencies under an adaptive management framework. Under the authority of the Fish and Wildlife Coordination Act, the USFWS will continue to provide technical assistance and coordination to the USACE as their funding permits. Asian carps are being considered in the planning of these fishways. Sites were selected where substantial numbers of Asian carps have been documented in the commercial harvest for over 10 years (Pools 26, 22, and 19), or are above the leading edge of the Asian carp infestation (Pools 8 and 4). In cooperation with the USFWS and state agencies, the USACE is currently developing fish passage alternatives for Lock and Dams 22 and 26.

**Recommendation 3.2.3.2. Require federal and state agencies to consider the potential range expansion and ecological effects of Asian carps when designing or reviewing water control structure projects and permits.**

Numerous government agencies are involved with projects affecting water control structures in both navigable and non-navigable waters. Many of these are falling into states of nonuse and/or disrepair, creating an impetus for removal. Natural resources managers commonly pursue opportunities to:

- remediate the ecological effects of barriers to aquatic ecosystems via dam removal or notching,
- construct fishways that bypass the barrier,
- construct boulder ramps and stair steps to the head of a dam,
- eliminate perched culverts, and
- re-install low-water crossings that impede fish passage.

These actions can greatly aid the expansion of feral populations of Asian carps, even in low order streams. All agencies involved in water control structure projects should take actions to develop policies that require consideration of benefits to Asian carps and other nonnative species, and likewise, potential adverse affects to native ecosystems due to expanding populations of these fish and other aquatic nuisance species.

Federal agencies such as the USACE, USFWS, and U.S. Forest Service (USFS) should take lead roles to enact such policies. Asian carp interdiction should be an on-going, long term commitment by these agencies. Those knowledgeable of Asian carps should be sought by and assist these agencies during water control structure permit reviews and project design.

**Strategy 3.2.4. Forecast, detect, and rapidly respond to new feral Asian carp introductions and range expansions.**

Persistent, active measures are needed to control the expansion of feral populations of Asian carps. Natural resources managers must accurately determine the current distribution of feral populations and anticipate where range expansions or introductions are likely to occur. Monitoring programs are paramount in the timely detection and effective utilization of Rapid Response Plans to prevent range expansions and eradicate new introductions. Rapid Response Plans typically take considerable time to develop. Thus, they should be developed well in advance of their anticipated need. The Illinois Dispersal Barrier Advisory Panel and rapid response program could serve as a model for the proactive development of an Asian Carp Rapid Response Plan.

**Recommendation 3.2.4.1. Develop an early detection Decision Support System to: 1) identify high risk locations susceptible to introductions or range expansions of Asian carps, 2) identify watersheds of special concern, 3) prioritize specific locations for implementing comprehensive early detection monitoring programs.**

An early detection Decision Support System is needed to effectively identify where Asian carp populations are most likely to expand and are likely to be most damaging. This Decision Support System will allow managers to focus monitoring or detection efforts in areas of greatest need and concern. It will effectively prioritize locations for establishment of early detection programs to reduce the risk that range expansion might occur undetected and allow for rapid response measures to be enacted. An effective prioritization scheme can help management authorities to effectively direct limited resources to critical areas.

A Decision Support System coordinator is essential to operate a clearinghouse to communicate with state and local agencies.

Research is needed to understand 1) which water bodies and watersheds are at high risk for Asian carps' range expansion, 2) which water bodies and watersheds are most amenable to rapid response, and 3) whether alternatives to rapid response may reduce the threat of introductions or range expansions.

**Recommendation 3.2.4.2. Adopt and/or adapt an Incident Command System to provide for national coordination and management of early detection and rapid response programs.**

Managing emergency actions after detection of Asian carps, such as rapid response and eradication, may be complex, confusing, and inefficient, because multiple agencies at the federal, state, and local levels will be trying to rapidly react within dynamic aquatic ecosystems. The single standard Incident Command System was developed in the United States almost 30 years ago to respond to wildland fires (http://www.nifc.gov/fireinfo/ics_disc.html). Incident Command System has become the benchmark standard for multi-agency emergency management and coordination, and provides an on-scene structure of management-level positions suitable for managing any incident. It is flexible, comprehensible, and logical; it has been adapted for hazmat, oil spill, riots, and extreme weather (hurricanes, flooding, earthquakes, etc.) events. Implementing a national Asian carp or aquatic nuisance species Incident Command System will require a concerted and sustained effort by a lead federal agency, consultation and coordination with state natural resources management agencies, multi-agency agreements, unified training, and dedicated funding. An Incident Command System would benefit from the designation of a single federal agency as the primary agency responsible for the management and control of nuisance species.

**Recommendation 3.2.4.3. Develop and conduct routine early detection monitoring programs in locations where risk of introductions or range expansions of Asian carps exists.**

Early detection is a key component in the control of feral Asian carp populations. Together, early detection and rapid response can prevent expanding feral populations or new introductions of Asian carps from becoming established in new locations. Effective early detection will trigger rapid response plans in sufficient time for responders to prevent range expansion.

Coordinated early detection programs should be developed based on the highest priority areas identified by the early detection Decision Support System (Recommendation 3.2.4.1). Early detection programs in interjurisdictional waters or in locations that could affect multiple governances should be part of a national strategy to contain Asian carps (Recommendation 3.2.4.2). In many situations multi-agency efforts will be needed to optimize available resources and effectively implement early detection monitoring programs. Multi-agency programs will inherently require additional time for agency coordination and planning.

Research is needed to develop effective and efficient sampling techniques for all life stages of Asian carps in a variety of habitats to provide for effective early detection monitoring and evaluation of rapid response efforts.

**Recommendation 3.2.4.4. Develop Rapid Response Plans that identify where rapid response actions can effectively eradicate Asian carps and how those actions will be carried out.**

Rapid response is not likely to effectively stop the advancement of Asian carps in all situations, therefore, guidelines must be established to identify when rapid response actions are warranted and feasible. A rapid response action will require preparation and consideration of factors including threshold for action (i.e., number of fish to warrant a response action), necessary permits/licenses, responding and lead agency, and action plan for implementation.

Rapid response actions may be feasible in a relatively small subset of locations because of constraints imposed by 1) the biology of the organism, 2) the physics of the water body in question, and 3) politics or other factors that would make an area unfishable or untreatable with a rapid response technique. A Rapid Response Plan will identify when and where rapid response actions are feasible and most effective.

To be most effective, guidelines for implementation must be established in advance of the need. This will require agreement among agencies on clear guidance on the following: what level of detection will trigger a rapid response, what response techniques will be applied for each situation, what permits are required, what personnel and equipment are required, and who will respond. All protocols, permits, staff, equipment, and funding must be in place and on standby prior to the need for it.

"The National Environmental Policy Act requires federal agencies to integrate environmental values into their decision making processes by considering the environmental effects of their proposed actions and reasonable alternatives to those actions" (USEPA 2005). To meet this requirement, federal agencies prepare a detailed statement known as an Environmental Impact Statement, a very time consuming process. To be effective, Rapid Response Plan by definition must be rapid. For the timely implementation of a Rapid Response Plan, the USFWS should seek a categorical exclusion for Rapid Response Actions. Categorical exclusions are "a category of actions which do not individually or cumulatively have a significant effect on the human environment . . . and for which, therefore, neither an environmental assessment nor an environmental effect statement is required" (40 CFR 1508.4; Council of Environmental Quality 1978).

Local community coordination and involvement is vital. Local stakeholders must be involved in rapid response planning so that their support for a rapid response action is solid. Lack of stakeholder support could derail rapid response. Involvement could include town meetings, press releases, fact sheets, and experts to answer stakeholder questions about why a rapid response may be needed and what the benefits to the local community might be.

**Strategy 3.2.5. Develop a system for notifying management and regulatory agencies of escapees from captive populations of Asian carps.**

State laws and regulations govern possession, culture, and sale of native and nonnative fishes. Each state has developed laws, rules, and policies relative to nonnative species. States that do not prohibit Asian carps may or may not require a nonnative species license and/or reporting. Licensing and reporting can be valuable tools to allow states to track non-native species within their jurisdiction. To achieve basin-wide reporting, states are encouraged develop a license and reporting system and coordinate their regulatory efforts regionally, and nationally. A central coordination mechanism, such as a national toll-free telephone number for reporting escapees, is needed so information is rapidly and widely available and to initiate a rapid response.

**Recommendation 3.2.5.1. Develop a database and communication network with agencies that regulate Asian carp possession.**

States should be encouraged to require the reporting of escapees. Information awareness campaigns should be implemented to create awareness about the need to contain Asian carps, as well as how and why to report escapees. Escapee reporting programs should be linked to rapid response assessment programs. Management agencies that regulate the possession of Asian carps should collaborate, potentially under the auspices of the Mississippi Interstate Cooperative Resource Association or the Southeast Aquatic Resources Partnership.

**Recommendation 3.2.5.2. Create an information sharing system with early detection monitoring and rapid response project managers.**

Coordination among natural resources management agencies responsible for regulating the possession of Asian carps, conducting early detection monitoring, and implementing rapid response programs will be aided by tools that facilitate communication and information exchange. States that require escapee reports should post them to a central information exchange, potentially an Incident Command System, a national toll-free telephone number, and a web site (e.g. Mississippi River Basin Panel or Mississippi Interstate Cooperative Resource Association).

**Strategy 3.2.6. Develop an information exchange network for agencies, organizations, and partners to communicate and share “real time” data to facilitate early detection and rapid response programs.**

The size and scope of the Mississippi Basin poses an extreme challenge to those organizations and individuals coordinating nonnative species management programs. Currently, information sharing is handled by the Task Force through the Mississippi River Basin Panel on Aquatic Nuisance Species. The panel has a website (http://wwwaux.cerc.usgs.gov/MICRA/MRB%20Panel%20on%20ANS.htm) and a ListServe which members can use to post messages and reports. The Panel currently includes membership from interested federal agencies, Mississippi River Basin states, and numerous stakeholders including the National Association of State Aquaculture Coordinators, Catfish Farmers of America, the Pet Industry Joint Advisory Council, B.A.S.S., and the Nature Conservancy. As the Panel continues to evolve, it could become a clearinghouse for information via automated or managed electronic exchanges.

**Recommendation 3.2.6.1. Develop a website and centralized databases to provide information on early detection and rapid response programs.**

Information exchange of real time data can be provided quickly and efficiently to agencies, organizations, and partners through a centralized database housed on a website dedicated to early detection and rapid response programs.

**Recommendation 3.2.6.2. Develop a list-server to provide a forum for information exchange.**

Information exchange can be provided quickly and efficiently through a list-server, where agencies, organizations, and partners can post questions to their peers and gather additional information about solutions being implemented by others.

**Recommendation 3.2.6.3. Utilize and support the Nonindigenous Aquatic Species Information Center for accurate and spatially referenced biogeographic information and the Nonindigenous Aquatic Species Alert System to track expansion.**

The Nonindigenous Aquatic Species Information Center (http://nas.er.usgs.gov) provides spatially referenced biogeographic information (scientific reports, online/real-time queries, spatial data sets, regional contact lists, and general information) which can be accessed by agencies, organizations, and partners via the Internet. Natural resources management agencies should adapt Standard Operating Procedures for supplying timely information to the Nonindigenous Aquatic Species Alert System to maximize its accuracy and utility as a real-time tool to track the expansion of Asian carps.

# Goal 3.3. Reduce feral populations of bighead, black, grass, and silver carps in the United States.

Reducing feral populations of Asian carps is consistent with management efforts to promote ecosystems based on assemblages of native species. The effects of Asian carps on native ecosystems are likely to be proportional to their abundance; therefore, reducing the numbers of Asian carps should ameliorate potential adverse effects within these locations, and lower the chance that these fishes will spread to new areas. Potential strategies for population reduction include: 1) enhancing commercial harvest through education, market research, gear development, and possibly financial incentives; 2) increasing recreational harvest; 3) biological controls (e.g., diseases, parasites, or predators); 4) release of sterile Asian carps; 5) release of transgenic Asian carps (including Daughterless Carp and Trojan technologies) developed to reduce the size of a target population via spread of a deleterious gene; 6) application of pheromones to enhance harvest or interfere with reproduction or recruitment; 7) habitat or hydrologic modification to favor native fishes over Asian carps or to facilitate harvest of Asian carps; and 8) use of piscicides. Considerable research is necessary to further explore the efficacy of many of these potential strategies.

To increase effectiveness, these potential strategies should be woven into an integrated management framework. Integrated management is a strategy used by farmers and environmental managers to plan and implement actions that maximize control of the target species while minimizing damage to the environment, including native plants and animals (Hart et al. 2000). The integrated management philosophy takes a holistic approach and uses a logical sequence of events to develop a plan that employs the best management options and control tools to restrict, reduce, and maintain the target species at levels of insignificant impact, while minimizing danger to the environment, human health, and the economy (Hart et al. 2000). Integrated management strategies that have worked well in agricultural and urban settings can be used to manage aquatic nuisance species that threaten native ecosystems (Hart et al. 2000). The Great Lakes Fishery Commission has implemented an integrated management approach within the sea lamprey control program (Great Lakes Fishery Commission 1992). An integrated management philosophy is warranted and should be employed in the identification of methods to eradicate or reduce and maintain populations of feral Asian carps at levels of insignificant effect to native aquatic ecosystems.

### Strategy 3.3.1. Determine life history characteristics and build population dynamics models of Asian carps in the Mississippi River Basin.

Development of scientifically sound and cost-effective sampling methods is essential to adequately monitor the distribution and abundance of Asian carps (Recommendation 3.6.2.1). Models of the populations and biomass of Asian carps must be developed and supplied with the required data. This will require substantial effort and commitment of resources, but these models are critical to determine whether biological, chemical, and physical efforts to reduce feral Asian carp populations are justifiable and likely to be successful. Substantial advancements have been made in Australia in the modeling of common carp populations to predict efficacies of different control efforts (Brown 2005). Asian carp population models for the Mississippi River Basin should adopt and adapt useful parts of these prior efforts.

#### Recommendation 3.3.1.1. Determine life history parameters of Asian carps in the Mississippi River Basin.

Understanding the success of Asian carps in establishing populations in new areas is essential to controlling their populations. While there may be similarities between the Mississippi River Basin and the native ranges of Asian carps, their interactions with an area of the world in which they did not evolve must be understood. Life history characteristics that need to be identified in the Mississippi River Basin include habitat and hydrology preferences for spawning cues, fecundity rates, and larval fish rearing; food preferences; growth rates; recruitment rates and life expectancy. This activity is critical to several strategies in this plan.

**Recommendation 3.3.1.2. Create population, biomass, and recruitment models for Asian carps**

Life history information can be used to create models of Asian carp populations in regions of the Mississippi River Basin. Priority should be given to modeling bighead and silver carps in regions where they are most abundant. Models should first attempt to predict the effects of harvest on available biomass and population of Asian carps. Understanding the available quantity of Asian carps for harvest is necessary before large amounts of money will be invested by private interests. Later models might be created that would be geared toward estimating the efficacy of other control methodologies.

The Illinois Department of Natural Resources is currently financing a study to estimate biomass of Asian carps in the Illinois River that could be available for commercial harvest. These data will be used for stock-recruit modeling to concentrate commercial harvest efforts at a segment of the population whose removal could most effectively reduce the total population (personal communication, Steve Shults, Illinois Department of Natural Resources).

The USFWS, Illinois Natural History Survey, and University of Nebraska-Lincoln are developing stock-recruit models for bighead and silver carps in portions of the Illinois and Mississippi Rivers (unpublished data, Michael Hoff, USFWS). Provisional results of the models imply that control of stock size can significantly reduce recruitment and total population size.

**Strategy 3.3.2. Increase the commercial harvest of Asian carps.**

Large biomasses of Asian carps are available and are harvested commercially in portions of the Mississippi River Basin (Maher 2002, 2005; FishPro 2004; personal communication, Jody David, Louisiana Department of Wildlife and Fisheries; personal communication, Brian Canaday, Missouri Department of Conservation).

Federal and state agencies should promote commercial harvest of Asian carps. This requires development of markets for the harvested fish and, in the short or medium term, may require incentives for harvesters (Appendix 6.6). Harvest enhancement should be focused on bighead and silver carps because they are the most abundant of the Asian carps in the system (Barko et al. 2005), and because the less abundant grass carp already fetches a reasonably high price (Maher 2002, 2005). Harvest or market enhancement specifically for black carp is not likely to be productive because of the extremely low abundance of black carp in the wild in the United States.

**Recommendation 3.3.2.1. Evaluate gear and harvest method effectiveness, develop new gears if necessary, and provide information to commercial fishers.**

Determine harvest methods that are effective in habitats where Asian carps are abundant. If habitats that are heavily used by Asian carps are not fishable with traditionally used gears, investigate non–traditional gears and if necessary provide education to commercial fishers. Some of the methods developed under Recommendation 3.3.1.1 to assess carp populations may be useful for increasing harvest by commercial fishers. Federal, state, or university agencies should determine the methods used by the most successful commercial fishers and transfer this information to other fishers and between basins.

**Recommendation 3.3.2.2. Increase the number of commercial fishers.**

Commercial fishing in the Mississippi River Basin is a very small industry with few and a decreasing number of full-time experienced fishers (unpublished data, Rob Maher, Illinois Department of Natural Resources). Economic returns are low and fishing is a secondary source of income to most commercial fishers. If the value of landed Asian carps were to increase substantially, the number of fishers would be expected to increase and fishers could be expected to fish more. Nevertheless, there may be some lag time between the generation of a market and an increase in the number of experienced fishers. Training and financial incentives might be provided directly to fishers by government agencies. Perhaps a more likely way to achieve this result would be the training, hiring, or contracting of fishers by processors and marketers.

**Recommendation 3.3.2.3. Examine commercial fishing regulations and consider changes to increase harvest.**

State agencies should examine commercial fishing regulations and consider changes to increase harvest of Asian carps, such as listing them as acceptable commercial species. The cost of licenses and other fees paid by commercial fishers should be examined to determine if modifications might encourage the harvest of Asian carps. One possibility might be to allow commercial harvest in areas that are currently off-limits to commercial fishing. However, prior to any regulation changes, the potential adverse effects on native species must be considered carefully. If necessary, gear types and seasons could be regulated in special areas to minimize adverse effects from opening new areas to commercial fishing. If the overall intensity of commercial fishing increases because of the advent of markets for Asian carps, it may be necessary to introduce regulations (for example, mesh size restrictions) that will minimize by-catch mortality of native species. Transportation of live wild-caught Asian carps should be prohibited except by permitted state and federal agencies or researchers.

**Recommendation 3.3.2.4. Provide financial incentives to commercial fishers to increase harvest of Asian carps.**

Increasing the economic return from fishing for Asian carps should increase harvest. This might be accomplished through subsidies, low interest loans, bounties, or contract fisheries (Appendix 6.6). However, the economics of the fishing industry in the Mississippi River Basin are not fully understood.

**Recommendation 3.3.2.5. Develop new markets for Asian carps.**

Federal or state agencies may need to provide low-interest loans or other fiscal inducements to speed the development of new markets for Asian carps (Appendix 6.6).

New products must be developed and test-marketed. Development of new products and markets might be done by private industry without federal or state inducements, but these activities will proceed faster if beginning risks and expenses are mediated by government entities. Markets for Asian carps in the United States are currently few and limited to primarily ethnic markets, where live fish are preferred but dead fish are also sold. Private enterprise has already recognized the abundant population of Asian carps as a low-cost protein source, and several entities are investigating possible new outlets for these fish. Because these are start-up businesses, they are high-risk endeavors and may require large capital investments. However, development of markets for Asian carps will enhance the value of landed fish and provide impetus for increased commercial fishing effort. Markets for commercially harvested Asian carps should be based on a dead product and marketing of live wild-caught Asian carps should be prohibited (see Recommendation 3.1.16.1).

State agencies are encouraging and working with private entities to investigate marketing of Asian carps. For example, the Missouri Department of Conservation has met with private corporations that have an interest in oils of bighead and silver carps, which are high in "good" cholesterol (Steffens et al. 1992) for the health food market and in marketing Asian carps for pet food (personal communication, Brian Canaday, Missouri Department of Conservation). Dr. Lynn Hannaman of Louisiana State University is developing an inexpensive device that will more efficiently chop large carps into manageable pieces for use as crab and crawfish bait. Private businesses are testing new products and markets, but for proprietary reasons it is difficult to determine the status of these efforts. The Illinois Department of Commerce and Economic Opportunity awarded a grant to the City of Havana, Illinois, to assist in a feasibility study for various fish products processed from Asian carps.

**Recommendation 3.3.2.6. Determine contaminant concentrations in edible portions of feral Asian carps.**

Contaminant concentrations in the flesh of Asian carps must be determined. Business interests will likely not invest capital to develop markets for the fish without knowing the risk posed by contaminants.

Contaminant concentrations generally are higher in fishes that are high on the food web, benthic, slow-growing, and long-lived (Schmitt et al. 1999). Bighead, silver, and grass carps grow quickly, feed low on the food chain, and are not primarily benthic (Kolar et al. 2005), therefore they are unlikely to have high contaminant concentrations compared to other fishes in the same system. Nevertheless, there is substantial chemical contamination of some of the rivers inhabited by Asian carps. A preliminary study on contaminants in bighead and silver carps collected in the Illinois River and the middle Mississippi River has been completed recently (Rogowski et al. 2005). By their methods, none of the fish exceeded any advisory concentration for polychlorinated biphenyls (PCBs) or chlordane, and mean values for mercury fell well below the most conservative advisory concentration bracket. These data are encouraging, but further work is recommended. In areas where Asian carps may be found to contain high contaminant levels, some of the alternative market uses listed in Recommendation 3.3.2.5 may be appropriate.

The Illinois Department of Natural Resources is funding further studies of contaminant concentrations in the flesh of bighead and silver carps in Illinois (personal communication, Steve Shults, Illinois Department of Natural Resources). The USGS will begin similar studies on fish collected from the lower and middle Missouri River in 2005 (personal communication, Carl Orazio, USGS).

**Strategy 3.3.3. Increase recreational harvest of Asian carps.**

Commercial harvest of Asian carps is likely to be more important than recreational harvest for the foreseeable future. Bighead and silver carps are primarily filter feeders and grass carps primarily herbivores (Kolar et al. 2005). Thus, they are difficult to take on hook and line, which impedes recreational harvest, although some are taken by rod and reel fishers, both on baits and by snagging. Asian carps are often targeted by bowfishers (Figure 3.3.1) who often take hundreds of pounds of Asian carps from a single boat in a day. The surface feeding behavior of bighead carp (Figure 3.3.2; Kolar et al. 2005) makes them susceptible to bowfishers. However, bowfishing is unlikely to have a substantial effect on the population of Asian carps because of the limited number of bowfishers. A limited recreational fishery for Asian carps exists when and where snagging is legal, but this fishery is not likely to remove the large numbers of fish required for population control. Methods for taking Asian carps with baits have been developed in Europe and Asia (Barth 2004), but North American anglers do not generally target Asian carps and have not yet embraced these techniques.

**Figure 3.3.1.** Bowfishers can take large numbers of bighead carp. This catch represents one outing by four fishers; the total weight of the fish was estimated between two and three thousand pounds. Picture courtesy of Bowfishing Association of Iowa.

**Figure 3.3.2.** Surface feeding behavior of bighead carp. Picture courtesy of Bowfishing Association of Iowa.

Nevertheless, additional harvest may be achieved by encouraging the use of Asian carps by recreational fishers. Asian carps are large, meaty fishes that are consumed avidly by consumers from Asian cultures, here and overseas. The flesh of Asian carps is considered by some to be high quality (Michaelson 1999; Stone et al. 2000; Chapman 2004). Although Asian carps have intramuscular bones that render the flesh undesirable to many North American recreational fishers, information on how to prepare the fish in ways that make the fish more acceptable is available (Chapman 2004). Harvest enhancement may be accomplished by angler education and by modification of regulations that might in some way hamper Asian carp harvest (e.g. harvest limits for non-game fishes).

Although in the short term enhancement of recreational harvest is not likely to cause a substantial decrease in the population of Asian carps, there is potential that over the long term harvest may become considerable. Costs of these efforts are low and benefits to the public accrue from the potential for decreased Asian carp populations and from the benefits of capturing and consuming the fish.

**Recommendation 3.3.3.1. Examine recreational harvest regulations to eliminate barriers to recreational harvest of Asian carps.**

States should examine their recreational harvest regulations in relation to patterns of Asian carp harvest. For example, the State of Missouri removed a limit of 20 non-game fish per day (Missouri Wildlife Code, 3 CSR 10-6.550). Illinois will soon add Asian carps to the list of species legal for snagging and bowfishing (personal communication, Steve Shults, Illinois Department of Natural Resources). Bowfishing at night is illegal in some states, yet bowfishing of Asian carps is especially productive at night (personal communication, Ron Cannon, Bowfishing Association of America). If regulatory changes can increase recreational harvest of Asian carps without endangering native species, then this may result in a low-cost harvest enhancement.

**Recommendation 3.3.3.2. Inform recreational fishers about Asian carp harvest and preparation methods.**

Provide information to recreational fishers on how to catch Asian carps and the culinary attributes of these fish. This could be enhanced by encouraging tournament-type events to increase recreational harvest. Establishing partnerships with chapters of the American Culinary Federation would encourage development of Asian carp recipes. A potential negative effect of this strategy is the possibility that some may eventually view these fishes as a beneficial species. Educational information for the public should include information on the positive environmental benefits of removing and consuming these species.

Stakeholders representing a cross section of interests should work with partners to develop appropriate outreach products for recreational fishers to encourage Asian carp harvest, cleaning, preparation and consumption. Angling and bowfishing for Asian carps should be promoted, including angling techniques, equipment, baits, and tournaments throughout the geographic distribution of feral Asian carps.

The Missouri Department of Conservation and the Illinois Department of Natural Resources have published articles describing techniques for catching and preparing Asian carps in their outreach publications (Perea 2002; Chapman 2004). The Native Fish Conservancy, together with bowfishing organizations and Bass Pro Shops, is organizing an Asian carp cook-off in central Missouri (personal communication, Robert Rice, Native Fish Conservancy).

**Strategy 3.3.4. Reduce populations of Asian carps through the introduction of biological controls such as disease agents, parasites, or predators.**

The introduction of *non-native* biological controls such as disease agents, parasites, or predators to reduce or eliminate Asian carps is not likely to be fruitful and it is <u>not</u> recommended. There are no known diseases or parasites that are likely to effectively control Asian carps that are completely specific to Asian carps (Kolar et al. 2005). It is also unlikely that any predator could be found that would prey only on Asian carps.

Stocking *native* predators (or otherwise enhancing their abundance) might reduce the recruitment of Asian carps, however little information is available on the susceptibility of Asian carps to native piscivores. Research is needed to determine which native predator fish can effectively prey on Asian carps, the vulnerability (sizes and life stages) of Asian carps to predation, and the stocking size and density of predators required for effective population control. The enhancement of native predators to control feral Asian carps should be pursued only after necessary research has been completed and with caution to prevent unintended effects to native prey fishes. Predator enhancement applications are likely to be limited by the number of appropriate locations and research in this vein is of medium priority.

Additional considerations for the use of disease agents, parasites, or predators as biological controls for feral Asian carps are provided in Appendix 6.7.

**Recommendation 3.3.4.1. Develop information on the factors that determine the efficacy of native predator enhancement to control Asian carps.**

The Department of the Interior and other natural resources management agencies should fund research into predator-prey relationships that affect Asian carps. Before beginning any artificial enhancement of predator densities or changes to species assemblages, the effects of enhancement must be well understood to avoid undesirable consequences or activities that are not cost-effective. This information is required for the biological control of Asian carps, assessing the risk of Asian carp establishment in new environments, and providing insights into habitat modifications that would make Asian carps more susceptible to native piscivores. An example might be in floodplain scours or backwaters inhabited by many juvenile Asian carps where predators are not abundant (perhaps limited by recruitment or physical access). Basic research on the early life history and ecology of feral Asian carps (Recommendation 3.3.1.1) and diet studies of native piscivores are critical needs that will provide insights and the ability to form testable hypotheses regarding control of Asian carps using native predators.

States and federal agencies should determine locations and timing where predator enhancement would be beneficial and cost-effective, and implement predator enhancement through stocking or other appropriate methods (predator harvest restrictions, habitat manipulations).

**Strategy 3.3.5. Consider stocking sterile carp or monosex tetraploids to inhibit reproduction and recruitment of feral fish.**

The introduction of sterile males has been effective in the control of some species of insects (Meyer and Simpson 1994). Preliminary evidence of effective sea lamprey control in the Great Lakes through the release of sterile male lamprey (Twohey et al. 2003) suggests that releasing sterile fish may hold promise in the control of other nonnative fishes; however, little research has been conducted on this topic (Kapuscinski and Patronski 2005).

Research is needed to explore the potential for release of sterile Asian carps as a control method (Kapuscinski and Patronski 2005), and is not currently recommended by the Working Group. The reduction of a target species via the release of sterile fish requires achieving a high rate of sterile to fertile males (Kapuscinski and Patronski 2005). The presence of large numbers of sterile male Asian carps may only marginally interfere with spawning, even if the sterile males behave like fertile males. Because female Asian carps are attended during spawning by several males (Chang 1966, Jennings 1988), if only one of the attending males is fertile, fertilization of the eggs is likely.

An alternative to the release of sterile males is the release of sex reversed, monosex, tetraploid (4n) males. Sex reversed, tetraploid males would interfere with the normal reproduction cycle of wild fish by fertilizing normal haploid (1N) wild eggs with diploid (2N) sperm thereby resulting in the production of only triploid (3N) sterile fish that can not continue to contribute gametes back into the wild population. Stocking of sex reversed, tetraploids males over an extended period could result in a substantial reduction of biomass of the targeted Asian carp species.

This strategy requires further research into the development of tetraploid fish, confirmation that it lead to sterile triploid progeny, and modeling of the required stocking rate of tetraploid male fish. If the technology for tetraploid grass carp production is improved so that large numbers of viable tetraploid fish are available, then it would be prudent to produce models to determine if stocking sex-reversed Asian carps constitutes a viable control method.

> **Recommendation 3.3.5.1. Examine the potential efficacy of introduction of monosex tetraploid fish as a control method.**
>
> Private industry and academic institutions are likely to continue to work towards the development of viable tetraploid stocks of Asian carps to be used in the production of triploid fish. If those efforts are successful, then the stocking of monosex tetraploid fish to control feral populations should be investigated and would require modeling to assess efficacy.

**Strategy 3.3.6. Research and apply transgenic manipulations (e.g., "Daughterless carp" and "Trojan gene" technologies).**

Genetic modifications (i.e., transfer of novel genetic constructs into the fish genome) that result in "transgenic" fish expressing a novel trait may be useful in controlling non-native fish populations (Kapuscinski and Patronski 2005). The release of transgenic Asian carps bearing a deleterious gene would disrupt part of the fishes' life cycle or biology. "Trojan gene" technology involves a transgenic fish with a novel construct that simultaneously confers one advantage, such as a mating advantage, that drives the transgene into the target population and one disadvantage, such as reduced offspring viability, that triggers a decline in the target population (Kapuscinski and Patronski 2005). Purposely releasing a transgenic fish expressing a deleterious gene for control of a non-native fish is a relatively new idea and much research is still required. Kapuscinski and Patronski (2005) discuss 6 deleterious gene spread strategies (including strengths, weaknesses, and other considerations) for the control of non-native fishes.

One promising strategy involves spreading a transgene designed to alter a target population's sex ratio. "Daughterless Carp" technology involves the use of a genetic modification to develop an all-male strain of fish. When these fish breed with "normal" fish of the same species, all the offspring are male. This trait is carried through subsequent generations until reproduction declines, or is finally eliminated, because of a lack of females in the population. A more detailed discussion of this technology is presented in Appendix 6.8. This technology could be an elegant solution to any nuisance fish problem, but the technology is in its infancy and success is not ensured.

Although no immediate actions toward development of daughterless Asian carps are recommended, this does not mean that the potential importance of this control technique is low.

This strategy is perhaps the only strategy yet identified that might eventually extirpate Asian carps from the wild in the United States. However, this strategy requires an extremely long-term outlook, and the timing of actions and expenditures should be prudently paced. Depending on the rate of advancement of this technology, it is possible that efforts directed at Asian carps could begin within three to five years.

**Recommendation 3.3.6.1. Adapt "daughterless carp" genetic technology to Asian carps.**

Advancements in the research and implementation of daughterless carp technology should be monitored closely. When and if successes in population control of common carp are evident or seem likely, then efforts to adapt this technology to bighead, grass, and silver carps should be undertaken as a high priority. This will require research to understand sex determination in Asian carps.

On-going research on daughterless common carp is underway in Australia (Commonwealth Scientific and Industrial Research Organization Marine Laboratories in Hobart, under the direction of Ron Thresher). Scientists transferred an aromatase blocker gene into zebrafish (*Brachydanio rerio*) and showed that significantly more males were produced than females. Laboratory studies are now concentrated on finding the best way to ensure the modified gene is passed on to offspring and developing a carp-specific modified gene.

**Strategy 3.3.7. Develop and apply pheromone baits to control Asian carps.**

Pheromones are odors or mixtures of odorous substances released by an individual that evoke a behavioral response in conspecifics or closely related species, requiring no prior experience or learning (Sorensen and Stacey 2004). The use of migratory and sex pheromones to control sea lampreys in the Great Lakes is currently under investigation (Li et al. 2003; Sorensen and Stacey 2004) and is in the field trial stage (personal communication, Gavin Christie, Great Lakes Fishery Commission). The use of pheromones has been proposed as a potential means for controlling other nuisance fishes such as common carp (Maniak et al. 2000; Sorensen and Stacey 2004). Sex or aggregation pheromones have potential for use as attractants or baits that can be used to enhance the capture of Asian carps. Pheromones have been implicated in the aggregation of juvenile common carp (Sisler 2005), but this research has not yet been performed with bighead, black, grass, or silver carps. If pheromones play a part in the observed long-distance spawning migrations of Asian carps or in the aggregation of the large schools of juveniles or adults, then Asian carp pheromones may eventually become useful management tools.

Research in pheromone attractants has a high chance of producing positive results. However, this technology will require years of development before it is useful in the field. Use of this technology will likely require artificial synthesis of pheromones and release of those chemicals into the environment. Pheromones are natural chemicals that are unlikely to have adverse environmental effects, but permits must nevertheless be obtained and legal hurdles overcome. It will be necessary to work closely with the USEPA to achieve the appropriate approvals. The use of pheromones in the control of sea lampreys should be an appropriate legal model.

When pheromones are developed that may have field application, they will need to either be extracted from harvested Asian carps or synthesized in large quantities and then tested in the field. One difference between Asian carp and sea lamprey control with pheromones is that the

Asian carps are a potentially marketable resource. This may make a difference in how and by whom the pheromones are applied. The most sensible approach may be to have commercial fishers use the chemicals instead of state or federal natural resources managers, or possibly managers and commercial fishers may work together.

**Recommendation 3.3.7.1. Sex pheromone research should continue with the goal of production and application of field-applicable technologies.**

Developing pheromone technologies for the control of Asian carps is a high priority. The USEPA and state agencies with similar mandates should work closely with researchers and those that would eventually apply the pheromones for removal operations so that the proper approvals can be obtained.

The use of bighead and silver carp pheromones is currently being assessed by Edward Little at the USGS Columbia Environmental Research Center in Columbia, Missouri. To date, these studies have focused on the use of alarm pheromones. Alarm pheromones may be most useful as deterrents or to deny the use of certain zones to bighead and silver carps, but they will have limited application in population control. Dr. Little is now beginning research on sex pheromones of bighead and silver carps.

**Recommendation 3.3.7.2. Investigate aggregation pheromones for juvenile Asian carps.**

The existence and potential uses of aggregation pheromones for juvenile Asian carps should be investigated. If such pheromones exist, they would constitute useful bait for the capture of small carps before they mature. Evidence for the existence of aggregation pheromones for juvenile common carp has been shown (Sisler 2005), but this has not been investigated in Asian carps.

**Strategy 3.3.8. Develop and apply habitat and hydrological manipulations that favor native species over Asian carps or that might be useful in harvest enhancement.**

The manipulation of habitat has many potential uses to control Asian carps (Appendix 6.9). Most such applications and their potential adverse consequences are not fully understood. Nevertheless, agencies in control of public lands and waterways should strive to understand the effects of land and water use and habitat manipulations on Asian carps and native fishes and changes should be made where appropriate.

Habitat manipulations to control Asian carps have the potential of undesired effects. For example, habitat conditions that favor native species may be similar to those preferred by Asian carps. Some native fishes will be adversely affected by migration barriers. The desirable and undesirable effects of habitat manipulations must be weighed before any such actions are taken, and the effects of habitat manipulation should be monitored to ensure that they are producing the desired results. A better understanding of the life history of Asian carps in the United States, as outlined in Recommendation 3.3.1.1, is critical to devising most habitat manipulation strategies.

**Recommendation 3.3.8.1. Provide technical assistance and biological information to the USACE and participate in collaborative planning of habitat improvement projects (e.g., Navigation and Ecosystem Sustainability Program, Missouri River Mitigation Project, and other authorities).**

The USACE is involved in multimillion dollar habitat and species restoration projects in the Mississippi and Missouri river basins. The USFWS and state conservation agencies should participate throughout the preparation of these plans, under authority of the Fish and Wildlife Coordination Act, to develop habitats that are more beneficial for native species than for Asian carps. Specifically, containment and control of the expansion of feral Asian carp populations should be a critical issue in the development of USACE plans for mitigation of adverse effects of proposed navigation improvements. Those involved in mitigation activities should evaluate and monitor mitigation projects and large-scale habitat manipulations for effects on Asian carp populations. Habitat and hydrological manipulations that can be economically and efficiently used to control Asian carps or to enhance the ability of fishers to remove Asian carps should be investigated, and used where appropriate. The adverse effects of such habitat modifications on native species should also be evaluated and monitored. Adaptive management should be used in further applications of habitat manipulations for control of Asian carps.

**Strategy 3.3.9. Investigate the sensitivity of Asian carps to piscicides, and examine the feasibility of chemical Asian carp control in specific habitats.**

Piscicides have been applied to ponds, lakes, streams, and rivers to control nuisance fishes for decades (Dawson and Kolar 2003). The toxicity of many chemicals to bighead, grass, and silver carps has been examined (13 chemicals, 34 studies for bighead carp; 75 chemicals, 233 studies for grass carp; 21 chemicals, 83 studies for silver carp; Pesticide Action Network 2005). Rotenone and antimycin are the only registered piscicides available to potentially control Asian carps in the United States without considerable additional expense. Rotenone and antimycin are both labeled for use in lakes and running waters (i.e., streams and rivers). The American Fisheries Society has published a manual for the use of rotenone in fisheries management (Finlayson et al. 2000). Research is needed to further investigate the effectiveness of registered piscicides to control Asian carps, evaluate their potential use in the control of feral populations, and to determine the potential of other chemicals to control Asian carps. Additional considerations in the use of piscicides to control feral Asian carps are presented in Appendix 6.10.

**Recommendation 3.3.9.1. Determine effectiveness of registered piscicides to control Asian carps.**

State, federal or university researchers should determine contact time required to kill bighead, black, grass, and silver carps using rotenone and antimycin under a variety of environmental conditions. The toxicity of rotenone and antimycin to black carp must be determined.

**Recommendation 3.3.9.2. Identify conditions where rotenone or antimycin could be used to control populations of Asian carps.**

The feasibility of using rotenone or antimycin to target Asian carps in backwaters or intermittently connected wetlands should be examined. Treatment plans should be developed where warranted. Other areas with concentrations of juvenile Asian carps might also be identified where rotenone might be a useful tool.

**Recommendation 3.3.9.3. Determine potential of other chemicals to control Asian carps.**

Asian carps may be susceptible to chemicals not currently approved for piscicide use in the United States. A review of chemicals used in other countries to control fish populations has been completed (Dawson and Kolar 2003). Laboratory studies to determine toxicity rates, effectiveness on Asian carps, and effects on native species should be conducted for identified potential chemicals. Development of new piscicides is expensive; registration costs alone can exceed $5 million dollars (Dawson and Kolar 2003). If effective chemicals are identified, formulations and application methods will need to be developed and environmental and human safety will need to be thoroughly investigated.

**Recommendation 3.3.9.4. Determine feasibility and applicability of piscicide bait deployment to control black and grass carps.**

In specific areas where black or grass carps are especially problematic, control using piscicide baits should be attempted. This will require research to develop and test baits specific for black or grass carps, and determine deployment methods that have limited affects on non-target organisms.

**Recommendation 3.3.9.5. Determine registration needs, if any, for the use of piscicides to control Asian carps, and ensure that piscicides are available for appropriate uses.**

The use of piscicides to control Asian carps may require unusual applications or new formulations (e.g., black carp bait). Changes to piscicide registrations may take time and be expensive. Federal dollars should be allocated, if necessary, to provide for any necessary registration changes.

# Goal 3.4. Minimize potential adverse effects of feral bighead, black, grass, and silver carps in the United States.

Once effects are accurately determined, it may be possible to minimize the undesirable effects of Asian carps by direct remediation of the effect. For example, if native fish populations are adversely affected, it may be possible to ameliorate these effects through direct stocking or other methods of population enhancement. It should be recognized that such efforts treat the symptoms of the problem rather than removing the causative agent, nevertheless such strategies may be advisable if the populations of key or threatened species are affected.

Undesirable effects of Asian carps that have been established can be mediated in ways other than reducing their populations. The jumping behavior of silver carp constitutes a new and serious threat to boaters and other recreationists. Severe personal injuries and damage to boats and equipment have occurred. Precautions can be taken to ameliorate this threat, but because this danger is new, many boaters are not aware of the threat and do not understand what precautions to take. Information programs to alert boaters and recreationists are required.

### Strategy 3.4.1. Enhance organisms adversely affected by Asian carps.

Specific long-term effects of Asian carps on native species are largely unknown, but undesired effects to some populations, such as, reduced numbers or even extirpation are possible and mitigation may be done directly. Potential actions to minimize these possible adverse effects include: removing animals from the wild to serve as captive broodstock, stocking individuals cultured at hatcheries, and physically protecting species such as mollusks from black carp by using enclosures. Populations of species most likely to be affected should be routinely monitored.

#### Recommendation 3.4.1.1. Monitor populations of species most likely to be affected by Asian carps.

Monitor populations of sensitive native species to determine actual and potential reductions in their abundance when they are in the presence of Asian carps, and determine whether or not there is a need for proactive management actions to prevent further decline or extirpation.

#### Recommendation 3.4.1.2. Restore or supplement numbers of native species through direct release (i.e., stocking).

If populations of fish or other organisms are reduced or extirpated through the activities or presence of Asian carps, then the affected species might be cultured and released in affected areas to enhance these populations. In fishes, this would be most effective if the affected life stage was a larval or juvenile form, in which fish larger than the affected life stage could be stocked. If black carp populations increase and are found to prey on native mussels, it may be necessary to expand on-going efforts to propagate such mussels to a size above which most predation occurs and to stock cultured mussels into the wild to maintain stocks of native species. If adult life stages are adversely affected through competition (e.g., native filter feeders, such as paddlefish), then such efforts would not likely be effective because the stocked fish would suffer the same effects as naturally recruited fish. Stocking fish, mussels, or other organisms is expensive, does not solve the problem, and potentially may create other problems. Complex questions involving such issues as genetic concerns and funding must be addressed before stocking plans are developed for fish or other aquatic organisms. Stocking programs should be developed as part of a comprehensive program designed to address the specific problems that are causing reduced populations of desired species.

**Recommendation 3.4.1.3. Protect or restore native species through methods other than stocking.**

Where possible, federal, state, and university researchers should accurately determine effects of Asian carps on the environment and undertake mitigation efforts where appropriate and feasible. Ongoing studies of the life history and effects of Asian carps may provide new methods to minimize the effects of Asian carps on native species. Actions may include: translocating mussels to uninfested watersheds or upstream of natural barriers, collection of wild individuals to serve as captive broodstock for perilously endangered animals, or using physical barriers to protect mussel beds from black carp. Another example might be to implant vegetation substitutes or construct grass carp exclusions in areas denuded by grass carp.

**Strategy 3.4.2. Minimize damage to waterway users that results from silver carp.**

Silver carp leap from the water when startled. Because watercrafts elicit this behavioral response in silver carp, these fish often jump into boats and cause damage to boaters and equipment (Figure 3.4.1). Although the speed and weight of the fish is sufficient to cause injury, fish that jump into rapidly moving boats have the additive effect of boat speed. These effects can be devastating and create a new source of danger for boaters in the central United States. Informing boaters is necessary to acquaint them to this threat and to provide recommendations on how to protect themselves.

**Figure 3.4.1.** Boater reacting to silver carp jumping into boat. Picture courtesy of Brian Johnson, U.S. Army Corps of Engineers.

Boaters can lower the possibility of being hurt or having their equipment damaged by jumping silver carp by understanding where these fish are most likely to be found (primarily low-velocity waters), by not following other boats because silver carp tend to jump behind boats, and by not waterskiing in silver carp habitat. Other things that can be done to minimize problems with jumping silver carp are the construction of guards that deflect silver carp from the boaters, or, very importantly, from the boat throttle. The throttle mechanism on small boats is often located on the gunwale where it is easily struck by jumping silver carp. When silver carp strike the throttle of a boat, the boat can respond violently and dangerously.

**Recommendation 3.4.2.1. Inform and train boaters to avoid damage from jumping silver carp.**

Informing boaters on the danger of jumping silver carp and how to avoid injuries and equipment damage should be a high priority. Education and information programs should be undertaken by both state and federal agencies, including state water patrols, Coast Guard Auxiliary, conservation agencies, USACE, USFWS, the National Park Service, and others. Information on this new hazard to boaters should be included in boating safety publications of states with silver carp, and included in other types of public outreach.

The Missouri Department of Conservation has released a press bulletin with information on how to avoid silver carp strikes, and included similar information on the television show “Missouri Outdoors”. Also, several media outlets (Doyle 2005; Cleveland 2005) have provided information to boaters on how to avoid silver carp strikes.

# Goal 3.5. Provide information to the public, commercial entities, and government agencies to improve effective management and control of bighead, black, grass, and silver carps in the United States.

There is a need to develop accurate science-based information concerning Asian carps and to develop an effective, nationally coordinated educational initiative that provides this information to diverse audiences. An effective education and outreach initiative will provide specific audiences with the information necessary to take actions and adopt practices that prevent accidental and deliberate unauthorized releases of Asian carps; and contain, reduce, and minimize adverse effects of feral Asian carp populations. A long-term education and outreach program is warranted to accomplish these objectives. This initiative must be dynamic to reach and effect desired results on the diverse audiences associated with Asian carps. The identification of needs and the development of information and education materials and programs should be a stakeholder participatory process that is led by the Task Force or an implementation committee (Recommendation 3.7.1.1). The Working Group suggested that the Task Force would be an appropriate organization to lead the coordination and implementation of this comprehensive national education and outreach initiative.

For greatest effectiveness, each component of the education and outreach program should be monitored, evaluated, and managed adaptively to ensure that objectives are being met.

**Strategy 3.5.1. Understand the specific information needs and the most effective approaches to reach and affect desired results with each key audience.**

The Working Group identified potential key audiences that should be engaged in a comprehensive education and outreach initiative (Table 3.5.1). Although the Working Group's knowledge regarding the education and outreach needs of some key target audiences is considered adequate, others are only poorly to partially understood (Table 3.5.2). Some information that is likely relevant to each audience can be developed immediately and with comparatively minimal effort. However, considerable work is needed to fully understand the education and outreach needs of many key audiences.

**Recommendation 3.5.1.1. Engage potential key audiences in the development of a comprehensive education and outreach program.**

The key audiences must be engaged and an understanding developed of how each audience can help to accomplish the goals of this plan. This understanding of each key audience is necessary to fully develop a comprehensive and effective education and outreach program. In addressing the education and outreach needs of each key audience it is essential to address the following: identify specific needs for information and education; identify the most effective approaches to reach and affect desired changes in each audience; gather and validate the credibility of materials; become both partners and leaders in planning, implementing, and evaluating; and identify gaps in knowledge or needs that can be addressed by applied or adaptive research.

**Table 3.5.1.** List of potential key target groups for which education and outreach needs are identified within this plan or need further assessment.

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**Academia and Research Community**
- Local extension offices
- Schools / Students
- Universities

**Commercial and Recreational Baitfish Harvesters**

**Commercial Fishers**

**Community Groups**
- Angler groups
- Community organizations
- Divers
- Lake associations
- Local extension offices

**Consumers**
- Food consumers
- Recreational and farm pond owners

**Marketers**
- Fish farms
- Live haulers
- Retail sales (grocers and pond stockings)
- Wholesalers

**Natural Resources Management Agencies/Organizations**
- Great Lakes Fishery Commission
- International Joint Commission
- Land Grant institutions
- Local municipalities
- Mississippi Interstate Cooperative Resource Association
- National Park Service
- Regional Aquatic Nuisance Species Panels
- Sea Grant institutions
- State Commerce agencies
- State DNR/DEC/DEP/AGR agencies
- State/County DOT agencies
- Tribal Natural Resources Management agencies
- U.S. Army Corps of Engineers
- U.S. Department of Agriculture
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- U.S. Department of Transportation
- U.S. Forest Service

**Table 3.5.1.** Continued.

| |
|---|
| **Pet Trade Industry** |
| Aquarium and water garden owners and hobbyists |
| Internet trade |
| Retail store owners |
| Wholesalers |
| **Producers and Growers** |
| Grow-Out facilities |
| Hatcheries |
| **Recreational Anglers and Boaters** |
| Boating and sailing clubs |
| Large- and small-scale bait/tackle shops |
| Marinas |
| **Transporters** |
| Consumers |
| Fish farms |
| Live haulers |
| Retail sales |
| Wholesalers |

**Table 3.5.2.** The Asian Carp Working Group's understanding of the education and outreach needs for potential key target groups.

| Target Groups | Understanding of Needs |
|---|---|
| Academia and Research Communities | Adequately Understood |
| Commercial Fishers | Adequately Understood |
| Commercial and Recreational Baitfish Harvesters | Adequately Understood |
| Natural Resources Management Agencies/Organizations | Adequately Understood |
| Recreational Anglers and Boaters | Adequately Understood |
| Community Groups | Partially Understood |
| Pet Trade Industry | Partially Understood |
| Producers and Growers | Partially Understood |
| Transporters | Partially Understood |
| Consumers | Poorly Understood |
| Marketers | Poorly Understood |

**Strategy 3.5.2. Prepare science-based materials based on key audience needs that can be used to develop curricula for effective education and outreach programs.**

A series of "informational modules" are recommended for the specific issues that are identified as critical to an educational and outreach effort. Specific education and outreach needs identified within other sections of the plan are listed in Appendix 6.11.

**Recommendation 3.5.2.1. Develop an information module that defines and describes Asian carps, efforts to contain and reduce feral populations, and sources from which to learn more about these fishes.**

Articles on Asian carps are presented frequently in the popular media, thereby introducing the issue of Asian carps to the general public. An information module is needed that provides accurate information on general issues relevant to Asian carps. These materials should include answers to some of the most general questions such as what are Asian carps, how did they get here, what is being done to contain and reduce feral populations, and how additional, accurate information about Asian carps can be obtained.

Many fact sheets have been developed already. Stakeholders representing a cross section of interests should work together to identify and evaluate existing materials, and to develop new materials for use in this information module. New materials need to be developed to provide a complete source of accurate information on these and other topics identified for a general information module. This module should serve as an introduction to anyone looking for accurate information on Asian carps and connect users to additional modules for more detailed information on the management and control of these fishes. The module could also be used for environmental education programs.

Once developed national media outlets such as news programs, media journalists, and educational television to provide nation-wide attention and accurate information regarding Asian carps. The support of well known celebrities associated with natural resources and angling (e.g., Bill Dance) to cooperate in these efforts.

**Recommendation 3.5.2.2. Develop an information module on the United States' Asian carp industry, size, scope, economics, and current farming practices.**

Accurate information on the history, size, scope, economics, and current farming practices with Asian carps in the United States is needed to develop credible education and outreach materials. These materials may be PowerPoint presentations, videos, fact sheets, and postings on web sites.

In many instances, an unproductive atmosphere between fish farmers and natural resources managers has developed because of mistrust and a lack of accurate information concerning farm practices. Accurate information and understanding by all parties are needed to forge productive partnerships. Accurate information on farming practices and site selection for fish farms is needed. There is a need for information on management of static ponds, their location with respect to natural waterways, levee elevations with respect to potential flooding levels, and water management on fish farms.

Currently, much information is available on proper siting, management, and construction of fish farms. Much of this information is available from land-grant university Cooperative Extensions programs and from state permitting authorities. The recent USEPA final rule for aquaculture effluents addresses new federal requirements for discharge permits (USEPA 2004). This rulemaking process also included survey information from regulated fish farms that may be relevant to this activity (USEPA rule web site: www.epa.gov/fedrgstr/EPA-WATER/2004/August/Day-23/w15530.htm). This information should be reviewed and summaries included in the information module for those unfamiliar with aquaculture practices.

The following educational materials are already available on current farming practices of carp in the United States:

- Fact sheets on the economics of raising bighead carp in mono and co-culture with channel catfish (Arkansas)
- Fact sheets on bighead carp production
- Fact sheets on the use of grass carp
- Fact sheets on the trematode infestations in catfish ponds
- Information on aquatic vegetation control
- Educational information on transporting warmwater fish

**Recommendation 3.5.2.3. Develop an information module on potential effects of Asian carps and reasons to contain and reduce their feral populations.**

Concern over the potential effects of increasing numbers of Asian carps has grown. Much of this concern stems from media materials highlighting the jumping abilities of silver carp, which can literally impact anglers and boaters. In addition to the potential harm to boaters, the public may not be familiar with the potential environmental effects of Asian carp. Species and habitat interactions make it very difficult to predict ecological effects when a new species is introduced into a new water body. Scientifically valid information on the effects of Asian carps in natural aquatic ecosystems is needed.

Much information exists and can be disseminated to a greater extent. Sources such as the *Foreign Nonindigenous Carps and Minnows in the United States - a guide to their identification, distribution, and biology* (Schofield et al. 2005); *Black Carp: Biological Synopsis and Risk Assessment of an Introduced Fish* (Nico et al. 2005); *Managing Aquatic Vegetation with Grass Carp* (Cassani 1996); the USGS Non-Indigenous Aquatic Species website (http://nas.er.usgs.gov/taxgroup/fish/default.asp); and various other publications are available. It is important that this information reaches the general public, governmental natural resources management programs, and aquaculture-related groups, such as, producers, sellers, and transporters so that an understanding of effects is realized.

It is also crucial to inform the public of the potential adverse consequences associated with the release of unwanted fish. Aquarium and water gardens, sport or commercially captured fish, stocked fish (e.g., farm ponds), and fish purchased live in food markets are some of the potential sources of unwanted releases. Materials such as instructions on the proper disposal of unused bait fish, environmentally safe procedures for draining farm ponds, and guidance on how to dispose of unwanted live fish need to be made broadly available to the public.

**Recommendation 3.5.2.4. Develop an information module on the identification of all life stages of Asian carps.**

The need for a module on the identification of all life stages for each of the four species of Asian carps has been identified for several target audiences including live haulers (wholesale and distributors), retail markets, food fish consumers, pond owners, natural resources managers, commercial fishers, recreational anglers, aquarium owners, and the general public. The ability of these stakeholders to correctly identify Asian carps is important in the prevention of accidental and deliberate unauthorized releases, as well as a critical component for early detection and rapid response efforts.

Currently, several educational materials are available for the identification of bighead and silver carps. Bighead and silver carp WATCH cards and posters are being distributed by the Illinois-Indiana Sea Grant, the USFWS, and several states. The cards identify adult fishes only, while the larger 11” x 17” posters have pictures of adult bighead and silver carps and compare juvenile bighead and silver carps with native gizzard shad. The Mississippi River Basin Regional Panel of the Task Force has posted a key to the identification of adult Asian carps on the Internet (http://www.asiancarp.org/Key/asiancarp%20key.pdf*)* and the USGS has recently published *Foreign Nonindigenous Carps and Minnows (Cyprinidae) in the United States – A Guide to their Identification, Distribution, and Biology.*

Several obstacles exist for this recommendation. Reaching individuals within identified target audiences may be difficult due to the diversity of these groups. Second, there is a lack of information for identifying juvenile stages of bighead and silver carps. Many target groups handle small bighead and silver carps, which are difficult to identify and distinguish from other species. Despite these obstacles, this is a high priority so that field personnel, the general public, and others included in this group can effectively begin and/or improve the accuracy of the early detection process. There should also be a long-term process of updating the module and materials.

**Recommendation 3.5.2.5. Develop an information module on why and how to report sightings of Asian carps.**

Agency field personnel cannot monitor all waters for the presence of Asian carps. This task can be more efficiently achieved by recruiting the interested public to help monitor and aid in the early detection of high priority aquatic nuisance species. Materials and training are needed to inform the public about the importance of reporting sightings, species identification, appropriate contact information, and their role as volunteer monitors.

Timely reporting by the public can assist natural resources managers in tracking the introduction and spread of Asian carps. Early detection and tracking of Asian carp migration and the monitoring of established populations will improve opportunities for rapid responders to successfully plan and implement control interventions or eradication measures. This may be especially beneficial near dispersal barriers and other waters of particular concern. Public assistance with the monitoring of Asian carps is critical for successful management.

There are several resources currently available for use in identification and reporting of sightings or catches. Bighead and silver carp WATCH cards and posters that contain

Asian carp identification and contact information are being distributed by the Illinois – Indiana Sea Grant, the USFWS, and several states. Fishing guide booklets from the State of Illinois and the Fishing Chicago Program contain information on how to identify bighead and silver carps, why they could be harmful to our natural resources, and how to report a sighting. Agency websites such as Alabama Department of Conservation and Natural Resources, Illinois Department of Natural Resources, Iowa Department of Natural Resources, USGS, and USFWS have information on why and how to report Asian carp sightings. Some of these websites contain information on all four species.

There are several obstacles to fulfill this recommendation. These include securing funds for materials and distribution, coordinating the contact information to report sightings, and determining whether materials will be issued by states, federal entities, or a regional association, such as one of the Regional Panels of the Task Force.

**Recommendation 3.5.2.6. Develop an information module on Hazard Analysis and Critical Control Point planning procedures.**

There is a need to distribute broadly a general description of the Hazard Analysis and Critical Control Point (HACCP) planning process and to provide guidance for more detailed information and points of contact for receiving training from the Sea Grant network or the USFWS. Knowledge of HACCP principles can help prevent accidental introductions.

An information module on HACCP principles has been identified for several target audiences including producers, growers, livehaulers (wholesale and distributors), retail markets, food fish consumers, natural resources managers, wild baitfish collectors, commercial anglers, recreational anglers, aquarium owners, and the general public. The ability of these stakeholders to correctly identify Asian carps is important in the prevention of unauthorized releases, and a critical component for early detection and rapid response efforts.

Sea Grant network conducts numerous Aquatic Nuisance Species- HACCP trainings throughout the country and has a recently updated manual, CD-ROM, and video that already incorporates Asian carps. USFWS conducts HACCP trainings in each of its seven regions. The USFWS Region 2 maintains the HACCP website (www.HACCP-NRM.org) which provides sample plans, the updated USFWS HACCP manual, a downloadable HACCP planning wizard, educational materials, and training announcements. The “Stop Aquatic Hitchhikers!” campaign describes general steps to remove nuisance plants and animals from recreational equipment. Although this is not a HACCP process, it may be more applicable for certain audiences within this group including recreational anglers and the general public who are less likely to employ an actual “HACCP“ plan.

Because HACCP implementation is not the only means to affect management controls at critical points to prevent spread of nuisance species, alternative management activities should also be recognized. This general information is not to be construed as mandatory for implementation of HACCP plans, especially among those industries which already address these pathways by other means. Rather, this should be used as an opportunity to distribute additional information as needed, or to assist in modifications to existing facility plans. Some industry segments may wish to pursue pathway management approaches such as following management practices recommended by the Extension Service or develop Best Management Practices with input from industry groups. Regardless of the method employed, documentation of management actions, and the process followed to evaluate and develop those actions should be maintained and periodically reviewed. It will be necessary to promote the importance and value of HACCP planning, especially for audiences that are not familiar with the program and who may be less than enthusiastic to adopt these principles.

**Recommendation 3.5.2.7. Develop an information module on the construction and maintenance of effective spillway barriers to reduce the risk of escape of Asian carps from private impoundments.**

Develop an information module and appropriate outreach products for recreational pond owners and commercial aquaculture producers to encourage the construction and maintenance of spillway barriers where Asian carps are being held. During heavy rain events, spillways may allow fish to move out of a pond. Appropriate measures must be taken to assure fish remain contained within designated target areas. However, recreational pond owners and commercial aquaculture producers have differing uses for these fish and therefore the educational programs designed will need to be specific to each group.

**Recommendation 3.5.2.8. Develop an information module to provide general information about regulations related to Asian carps.**

Stakeholders representing a cross section of interests should work with audiences identified in this recommendation to identify obstacles to communicating regulatory information that will result in a reduced risk of accidental and deliberate unauthorized Asian carp handling, possession, sale or release. Asian carp regulations vary from state-to-state, or city-to-city, as well as between and within states. There is widespread confusion and lack of up-to-date information. States advertise rule changes through administrative publications and/or news releases that are of limited distribution. A small number of outdoor writers publish articles sporadically in regional or local newspapers. These announcements are not always noticed by the general public or may blend in with other news items. Effective communication will be challenging because of competing stories in the media and a sense of information overload by the public in the United States media.

# Goal 3.6. Conduct research to provide accurate and scientifically valid information necessary for the effective management and control of bighead, black, grass, and silver carps in the United States.

Natural resources managers need scientifically valid information to effectively manage and control Asian carps. Research is needed to determine the distribution and abundance of populations; develop methods to contain Asian carps with minimal effects on native fishes; develop an effective control program that does not adversely affect native species and their habitats; and to develop ecological models that predict accurately where Asian carps will become established, and the nature of their ecological interactions within aquatic food webs. Additional research is needed to quantify ecological and economic effects of Asian carps and to develop methods that minimize the adverse effects of populations, or individuals in the case of black carp. To answer these questions with scientifically sound information, targeted research is needed in four broad areas: 1) fundamental biology and life history, 2) development of effective sampling gears and control methods, 3) assessment of ecological and economic effects of current and potential Asian carp populations, and 4) development of economically viable and environmentally safe alternatives to use of Asian carps.

A fundamental understanding of Asian carp biology and life history requirements in waters of the United States underpins nearly all other areas of potential research in the development of management options to control these species. Concurrent development of effective sampling gears and physical, chemical, or biological controls is required to estimate reliably the abundance of Asian carp species and the potential for reducing or preferably eliminating feral populations. The ecological and economic effects of introductions of Asian carps need to be quantified and accurate, predictive models developed to provide managers, stakeholders, and the general public with accurate information concerning the effects of introductions. Some Asian carps currently have valued applications in aquaculture, lake and recreational pond management, and are in demand as a food source (human and animal); therefore, research efforts need to develop improved methods for the safe use of these species, or derive ecologically and economically safe alternatives.

Many research recommendations have been identified in previous sections of this plan and are listed in Appendix 6.12. Where appropriate, recommendations listed here only summarize the detailed narratives and justifications in these earlier sections.

**Strategy 3.6.1. Assemble information about the distribution, biology, life history, and population dynamics of bighead, black, grass, and silver carps.**

Fundamental biological and life history information provides the foundation to manage fish populations and is essential to several goals of this management plan. General information of the life history and distribution of all four species were described by Fuller et al. (1999). Comprehensive biological synopses have been completed for each of these species (Shireman and Smith 1983; Cassani 1996; Kolar et al. 2005; Nico et al. 2005), however, relatively little research has been completed on the biology and life history of feral Asian carps in river systems of the United States. Management-oriented strategies and procedures based on research are needed to effectively prevent accidental and deliberate unauthorized introductions, contain and control populations, reduce population abundances, and minimize potential adverse effects.

Michael Hoff, Andy Starostka (USFWS); Duane Chapman, Cindy Kolar, Diana Papoulias (USGS); John Dettmers, John Chick (Illinois Natural History Survey); Mark Pegg (University of Nebraska); and Valerie Barko (Missouri Department of Conservation) are some of the scientists currently involved in investigating life history and population dynamics of Asian carps in the Mississippi River Basin.

**Recommendation 3.6.1.1. Describe current and temporal changes in distribution to better understand the invasion and colonization process.**

Understanding the distribution and spread of bighead, black, grass, and silver carps in the United States is essential to developing targeted control strategies for these species. Watersheds currently uninhabited by each Asian carp species need to be identified so efforts to prevent expansions into these areas can be prioritized. Although some field studies on distribution are underway, generally they are of limited scope and will not provide all information needed. Assessments of the biotic and abiotic factors that contribute to the distribution and abundance of feral Asian carps in different watersheds are needed. Unpublished results in agency and university reports are often difficult to locate or obtain and conclusions based on them should be considered as tentative until supported by peer-reviewed materials. Mapping the current distributions of each Asian carp species requires focused effort to collate previously reported sightings and to initiate specific research studies in vulnerable watersheds. Accomplishing this task will require coordinated efforts by federal, state, tribal, and provincial agencies; universities; and commercial fishers to compile recent maps that will provide the requisite data to analyze and understand the invasion and colonization processes. Knowledge of past routes of invasion and rates of colonization by each species can provide insights to prevent further spread. This task is also dependant upon the development of effective sampling methods (Recommendation 3.6.2.1).

**Recommendation 3.6.1.2. Describe movements and distribution of Asian carps in waters of the United States (e.g., habitat preference, habitat selection, and habitats used).**

Understanding habitat use and preferences for these species is essential to developing targeted control strategies. Information about distribution, probable natural limits to range expansion (e.g., temperature, latitude, etc.), and the effects of nuisance populations (e.g., trophic interactions and competition) are required to refine predictions about potential interactions of Asian carps with native aquatic species. Delineation of habitat use for all life stages of Asian carps may identify vulnerable points in each species life cycle where population control or eradication is feasible.

**Recommendation 3.6.1.3. Describe diets, evaluate food selection and availability, estimate food consumption, and assess feeding interactions (i.e., predation and competition) with native biota (trophic ecology).**

Understanding food webs, especially at lower trophic levels is necessary to evaluate competition and to predict effects on aquatic biota and ecosystems. Food consumption patterns are well documented for grass carp (Cassani 1996) and food consumption research is ongoing for black carp. When combined with information about diet, food selection and availability, habitat selection, food consumption estimates based on bioenergetics models should allow reliable predictions of dietary and other ecological interactions between Asian carps and native fishes. Development of bioenergetics models requires fundamental research on consumption rates, thermal tolerances, and metabolism of Asian carps (Recommendation 3.6.1.4). Once developed, bioenergetics models provide managers and researchers with a powerful tool to study energy flow in ecosystems, predator-prey interactions, habitat quality, and the bioaccumulation of toxic chemicals (Hansen et al. 1993).

**Recommendation 3.6.1.4. Assess ecologically important aspects of physiology and behavior such as environmental tolerances, endocrine functions, and sensory capabilities.**

This recommendation provides a foundation to predict abundance, distribution, and routes of dispersion. Physiological and behavioral information will provide the basis for other important research topics, such as developing attractants, repellants, and barriers or predicting interactions with other species through predation or competition.

**Recommendation 3.6.1.5. Estimate key population variables such as mortality, emigration and immigration, growth rates, fecundity, and stock-recruitment relations for population modeling.**

Effects of Asian carps and the degree to which the effects are negative will depend upon their population sizes (i.e., number of individuals or biomass). Population growth and size can be predicted with models (Quinn and Deriso 1999) that require accurate input about vital population rates (mortality, emigration and immigration, growth, and reproduction) and stock-recruitment relationships. Estimating growth rates will first require developing age assessment procedures (DeVries and Frie 1996) that are valid for long-lived fishes throughout broad climatic ranges.

**Strategy 3.6.2. Develop effective sampling and control methods for all life stages of Asian carps in both standing and flowing water environments.**

Development of scientifically sound and cost-effective sampling methods is essential to adequately monitor the distribution and abundance of Asian carps. To control distribution and, where possible, eliminate unwanted populations, techniques to contain and eradicate all life stages of Asian carps are needed. Population control methods (physical, chemical, and biological) need to be developed to control the abundance of Asian carps, without unintended effects on native species and their habitats. Field assessments and predictive models that estimate effects of various control measures are needed.

In some situations, sampling methods and control/eradication methods may be the same. Effective attractants could increase the effectiveness of sampling and control methods while repellants may increase the effectiveness of physical barriers to movement. Population control by physical removal may be possible, however additional research is needed. Managers have experimented with several methods (e.g., herding, angling, attracting, lift nets, and toxic fish baits) for removing grass carp from lake systems, however all techniques failed to remove a major portion of the carp population (Hoyer et al. 2005). Commercial catches of bighead and silver carps with hoop nets have been substantial in selected locations, suggesting that fishing gears are available for sampling these two species. Most commercially harvested black carp have been reported to have been collected in hoop nets (Nico et al. 2005). For commercial fishing to be an effective tool to control Asian carps in public waters, research is needed to evaluate the economic viability for developing markets that use these species. Potential uses include human food, animal feed, fertilizers, and an array of other products.

**Recommendation 3.6.2.1. Develop and evaluate effective methods for sampling feral populations of Asian carps.**

Conventional sampling methods have not been effective for determining the distribution and abundance of Asian carps (Stancill 2003). Effective management requires reliable estimates of Asian carp abundance to track populations over time, and to target and evaluate control efforts. Gear evaluation studies must be conducted under a variety of habitats, seasons, and environmental conditions to ensure gear accurately reflect the actual abundance and size distributions of these populations (Hayes et al. 1996).

**Recommendation 3.6.2.2. Develop and evaluate effective attractants and repellents.**

Attractants (chemical, physical, or biological) can be used to concentrate fish for sampling or population control. Species-specific attractants (baits, pheromones, or other unknown chemicals) may be used, for example, to concentrate grass carp in areas targeted for aquatic vegetation reduction, thereby increasing the effectiveness of biological control and reducing the numbers of grass carp that need to be stocked. Repellants (chemical, physical, or biological) may be useful in reducing the spread of Asian carps by increasing the effectiveness of barriers in large river systems.

**Recommendation 3.6.2.3. Evaluate existing piscicides and, if necessary, develop new piscicides that are selective for Asian carps.**

Sea lamprey in the Great Lakes have been controlled using chemicals that target and kill larval sea lamprey (www.glfc.org/seaslamp/how.php). The feasibility of targeting Asian carps with toxicants should be investigated. The effectiveness and selectivity of piscicides currently registered for use in the United States for bighead, black, and silver carps have not been evaluated sufficiently and new piscicide development efforts are not underway at this time. Development of new piscicides is expensive; costs of research to support registration can exceed $5 million dollars for each chemical (Dawson and Kolar 2003). If effective chemicals are identified, formulations and application methods will need to be developed and environmental and human safety concerns will need to be investigated thoroughly.

**Recommendation 3.6.2.4. Develop effective physical and behavioral barriers for controlling the movement of Asian carps.**

Behavioral fish guidance technologies include various methods of deterring or influencing fish movement by eliciting behaviors through sensory stimulation (Coutant 2001). Evaluations of any proposed dam removals must include the risks of expanding Asian carp distributions into uninfested waters, potentially causing more harm than good to native biota. The need for effective barriers to prevent the continued spread of Asian carps into uninhabited waters is a high priority; and requires more complete biological and physiological information about these fishes (Recommendation 3.6.1.4).

**Recommendation 3.6.2.5. Evaluate the potential for commercial harvest of feral Asian carps to control their abundance in public waters.**

Development of commercial uses of Asian carp biomass potentially could reduce abundance in the wild and concurrently provide useful products. Commercial fishers report high catch rates of bighead and silver carps in some locations, suggesting that harvest to regulate the abundance of these fishes may be a practical alternative. A limited market currently exists for bighead carp as human food, but this specialized, ethnic market prefers purchase of live fish. Proposals also have been made to commercially harvest Asian carps for pet foods, fish meal, surimi, and bio-fuel. If commercial harvest can be demonstrated to control Asian carp abundance in public waters, additional research will be needed to evaluate market acceptance of wild-caught, processed (e.g., dressed whole, fillets, smoked) Asian carps (Recommendation 3.6.4.2). If attractants can be developed, catches would increase, thereby benefiting commercial fishers while further reducing Asian carp populations. Additional research is needed to confirm the potential bioaccumulation of persistent toxins in these fishes and their suitability for human consumption, use as fish meal in aquaculture, and use as feedstuffs and fertilizers in agriculture.

**Strategy 3.6.3. Determine the demonstrated and probable ecological and economic effects of Asian carps in the United States and determine the degree to which these effects are negative.**

The adverse ecological and economic effects of certain nuisance species in North America have been estimated in several scientific papers (e.g., Mills et al. 1994 for Great Lakes) with worldwide extrapolated costs based on estimates exceeding 300 billion dollars annually (Pimentel 2002). Food habit information alone indicates that Asian carps will likely affect native biota through competition, which may affect valuable sport fisheries. However, the extent to which native species and ecosystems may be affected by Asian carps has not been quantified. Scientifically valid assessments of ecological effects are imperative to effective management and resource allocation decisions. Addressing this strategy will require much research specified above (Strategies 3.6.1 and 3.6.2), as well as, analyses and modeling of population dynamics, dispersal, and bioenergetics.

Predicting economic effects of Asian carps should include all societal costs of remediation, monitoring, attempted eradication or control, and lost recreational and commercial opportunities that use native fauna, and the market evaluation of the aquaculture industry. Basing management decisions on realized effects is clearly less risky than basing such decisions on predicted effects. Ideally, effective management incorporates predicted economic and ecological effects into the decision making process; however, managers should not wait until large populations create actual and realized problems before taking action.

Decisions regarding the management and control of Asian carps can have an economic effect on facilities producing farm-raised carp species and associated businesses. Asian carps contribute to the supply of human food, the control of economically important parasites of farm-raised fishes, and to control nuisance aquatic vegetation. Policy makers need accurate and comprehensive information on all facets of conflicts and issues. Consideration of the economic effects on the aquaculture industry is also required for assessments to be comprehensive. Economic effects to the United States farm-raised Asian carp industry that have not been thoroughly studied include: 1) economic trade-offs of aquatic vegetation control with grass carp versus alternative control methods; 2) economic losses mitigated by snail control using black carp in the catfish, minnow, and bass industries; 3) economic effects of banning live sale of bighead and grass carps for ethnic food markets; and 4) mandatory use of triploids only.

**Recommendation 3.6.3.1. Assess the ecological effects of bighead, black, and silver carps on individual aquatic species and aquatic ecosystems.**

In North American watersheds where Asian carps have become established, field inventories and research should commence immediately to document any changes in the distribution, abundance, and growth of native aquatic fauna. Black carp are thought to have high potential to reduce populations of native mussels, including numerous imperiled species, through direct consumption (Nico et al. 2005). Bighead and silver carps are primarily planktivores. If plankton availability is limiting, food consumption rates and abundances of Asian carp populations could disrupt food webs, thereby altering aquatic ecosystems. Limited studies to date indicate competition for food resources might be possible among bighead and silver carps, gizzard shad, and bigmouth buffalo (Sampson 2005) and age-0 bighead carp and age-0 paddlefish (Schrank et al. 2003). Further study of dietary overlap of Asian carps and native fish species, particularly juvenile fishes is needed. Alternatively, bighead and silver carp fry and small juveniles may serve as additional prey for native species; however, these fish grow rapidly and would probably outgrow the feeding abilities of native piscivorous fishes in a short time (Kolar et al. 2005). Modeling the interactions of Asian carps with native fishes and other aquatic species based on laboratory and field studies will help to predict their potential ecological effects and will help decision makers to target funds for control strategies.

**Recommendation 3.6.3.2. Document the actual ecological effects of bighead, black, grass, and silver carps.**

Comparing conditions before and after ecological disruption, such as colonization by a nonnative species, is an accepted method to assess effects of disruptions (Bernstein and Zalinski 1983; Stewart-Oaten et al. 1986), but validated information to make these comparisons is often lacking (Meroneck et al. 1996). Establishment and maintenance of long-term ecological monitoring programs are invaluable to detect ecological change (e.g., Oneida Lake, New York United States; Mayer et al. 2001). Comprehensive assessments should be encouraged immediately in areas where Asian carps are likely to expand to provide baseline data before these potential invasions. Although, this research objective seems to entail a “wait and see” approach to an inevitable invasion of some watersheds by Asian carps, documentation of ecological changes will improve predictive ability for risk assessments of uninfested waters. Thus, information about distribution and paths of invasions are needed to select ecosystems for assessment

**Recommendation 3.6.3.3. Conduct analyses of economic effects.**

Economic analysis is defined as “the study of how best to use limited means to pursue unlimited ends” (Baumol and Blinder 2005). Given the reality that “virtually all resources are scarce, choices must be made among a limited set of possibilities.” Economics is the discipline that provides the framework for quantifying the possible outcomes of various decisions that affect the allocation of resources. In the context of the effects of Asian carps, economic analyses must include both direct effects to people and to non-market valuation of native natural resources. Consideration must be given to issues such as effects on tourism (e.g., sport fisheries), changes in landings by commercial fishers, and effects on imperiled species, native fishes, and water quality. Indirect effects on the economic segments related to both commercial and recreational fishing, aquaculture infrastructure, and related businesses must also be included. Effect analyses, typically IMPLAN® -based input-output models (Minnesota IMPLAN Group Inc. 2005), or social welfare models (Green 2000), need to be constructed to determine the: 1) value of current Asian carp uses (e.g., aquatic vegetation control by grass carp, bighead carp production for human consumption, snail control by black carp, etc.); 2) societal and ecological costs due to feral populations of Asian carps (e.g., loss of endangered or imperiled species); 3) economic effects of proposed policy options (e.g., prohibiting sale of live fish, banning use of black carp, mandatory use of triploids, etc.); and 4) economic losses to fishing and boating industry.

**Strategy 3.6.4. Develop economically viable and environmentally safe alternatives to the uses of farm-raised Asian carps.**

Research is needed to develop environmentally safe and economically viable alternatives for the use of farm-raised bighead, black, and grass carps (Strategy 3.1.13). Black carp are used to control snails and prevent infestations of digenetic trematodes that adversely affect aquaculture production of several economically valuable food and bait fishes. Grass carp have proven to be an effective and economical solution to aquatic vegetation management in public and private waters (Cassani 1996). Bighead and silver carps are thought by some to be effective at reducing nuisance phytoplankton blooms in polyculture with channel catfish (Henderson 1980); however, this perceived benefit is equivocal (Stone et al. 2000). Bighead and grass carps are also shipped live to retail seafood markets in some major United States and Canadian cities, but these markets are poorly understood; thus it is difficult to hypothesize feasible substitutes at the present time.

Research is needed to develop environmentally safe alternatives to the use of bighead, black, and grass carps as biological controls. Research to identify feasible alternatives to the use of black carp for biological control of snails is the highest priority. Alternatives to grass carps for biological control of nuisance aquatic vegetation, especially triploid grass carp, is a lower priority than finding alternatives to the uses of other Asian carps for biological control.

Research is also needed to develop environmentally safe alternatives for the live seafood markets. Characterization of current ethnic markets for live fish and fresh fish on ice is needed. Consumer preferences for product attributes such as species, size, product forms and associated prices need to be determined to assess potential substitutes for the current live sale of bighead and grass carps in ethic food fish markets. The market potential and economic feasibility of growing and selling triploid fish for food are unknown. Additional useful research may include measures to improve the safety of hauling trucks and tanks such as improved latch systems and trigger systems to release rotenone in the event of a truck overturn to further reduce risks related to unintentional escapes.

**Recommendation 3.6.4.1. Evaluate ecologically safe and economically viable alternatives to black carp for snail control.**

Additional research is needed to seek alternative technologies using native species for biological control and/or chemical treatment of snails. Fundamental biological and physiological research of *Bolbophorus* spp. (trematodes) should be assessed to elucidate potential vulnerabilities in the parasite's life cycle where effective controls are feasible. Combinations of native fishes (species, sizes, densities) to effectively control the intermediate snail host should be tested. Potential chemical controls to disrupt any or all stages of the life cycle of parasitic trematodes including eradication of the primary intermediate snail host, prevention of snail immigration into aquaculture ponds, and the direct treatment of infected fish must be evaluated. Use of targeted chemical treatments for snail control based on season, temperature, and water chemistry of ponds, as well as, the size (life stage) of the production fishes should also be investigated.

Combinations of biological control with native species and limited chemical treatments should also be assessed. Based on economic effect analyses the potential to combine various biological and chemical control alternatives should be evaluated. All management alternatives, biological control, chemical treatment, or some combination thereof need to be tested on a commercial scale.

**Recommendation 3.6.4.2. Characterize ethnic markets for live fish and for fresh fish on ice. Determine consumer preferences for various attributes including size, product form, and price.**

Additional levels of environmental safety can be achieved by killing bighead and grass carps at the point of sale or by hauling the fish fresh on ice. Understanding the current market for live fish, for fresh fish on ice, and the preferences of consumers in these markets, is paramount for development of feasible alternative products. Descriptive information on sales volumes and pricing of the various sizes, species, and product forms is required to develop hypotheses related to potential substitutes for Asian carps. Quantitative consumer preference analysis (Green 2000) is necessary to identify those specific product attributes (i.e., live or fresh on ice, whole, whole-dressed, filleted, canned, size, and species) that are most important in consumer choices of fish products. When combined with the information about sales patterns, consumer preference analysis should allow reasonable predictions of the types of species and product forms that can be substituted for Asian carps or to what extent fresh fish on ice can be substituted for live fish.

**Recommendation 3.6.4.3. Evaluate the economic feasibility of growing and selling triploid bighead and grass carps for the live and fresh-on-ice markets.**

Use of triploid bighead and grass carps for the food fish markets would lessen the environmental risk of spreading these species to the wild during rearing, transport or after the sale. Determining economic feasibility requires both market analysis and analysis of production costs. Price and quantity information for both bighead and grass carps for each product form will provide the basis for assessing the market and, ultimately, the economic feasibility of these products. The costs of producing triploid bighead and grass carps need to be estimated to compare with projected market prices to determine if their production and sale will be feasible. Increased costs resulting from lowered yields due to slow fish growth have been well documented in the aquaculture economics literature (Engle and Hanson 2004; Jolly and Clonts 1993; Shang 1990). Tave (1993) reported that triploid bighead carp grew more slowly than diploids and there have been anecdotal reports of slower growth of triploid grass carp when compared to diploids. Additional pond trials are needed to quantify differences between triploid and diploid growth rates using various diets, stocking densities and sizes. According economic costs from lowered triploid growth rates along with comparisons of production costs and market prices will provide the basis to determine the economic feasibility of replacing diploid bighead and grass carps in the food fish markets with triploids. If it is determined to be economically feasible, educational efforts and regulations should be directed towards working to substitute triploid bighead and grass carps for the diploid forms currently sold in some markets.

## Goal 3.7. Effectively plan, implement, and evaluate management and control efforts for bighead, black, grass, and silver carps in the United States.

Bighead, grass, and silver carps, have become established as reproducing populations over a large geographic range in the central United States and probably will continue to expand unless a concerted, proactive effort is made to restrict their spread. A nationally coordinated approach is required to successfully implement this plan by employing effective management and control interventions. Numerous strategies and plans to control and manage Asian carp species are actively being developed by federal, state, and tribal agencies; non-governmental organizations (NGOs); private commercial interests; and the public. Each of these groups has a vested interest in preventing the dispersal and colonization by Asian carps in additional aquatic ecosystems of the United States. Implementation of this plan will be most effective when the efforts of these diverse groups are integrated within nationally or regionally coordinated strategies.

Management and control of Asian carps are especially challenging because of different perspectives and interests among the various consumer groups for commercial and recreational uses, and the natural resources management agencies charged with the responsibility to manage, conserve, and preserve aquatic ecosystems. These contrasting perspectives and interests result in different priorities and approaches for managing, controlling, or eliminating Asian carps. Some segments of the aquaculture industry are engaged in producing and marketing bighead, black, and grass carps for a wide range of uses by consumers, while natural resources management agencies are developing plans to minimize or eliminate potential adverse effects of feral populations on native species. The involvement of diverse stakeholders and the potential for conflicting interests warrants the development of a defined process for conflict resolution.

With any plan it is necessary to identify how it will be put into action. Strategies and recommendations can be developed, but to successfully and efficiently manage and control Asian carps, these plans must be funded adequately, put into action, and effectively sequenced and coordinated. Estimated costs for implementation of all Recommendations contained in this plan (years 1-20) are approximately $286 million (see Table 4.1, page 115). Limited funding will require that recommendations be prioritized and implemented in accordance with their strategic importance. Advance planning and coordination are essential to determine the availability of resources (e.g., staff, equipment, expertise, and funds), to effectively integrate and mobilize these resources, and to determine methods for evaluating success. There is much to learn regarding management and control of Asian carps, and it is essential that new information be readily assimilated into the management framework, and that strategies and recommendations are refined accordingly.

One approach to address these challenges is to establish formal institutional agreements and arrangements that facilitate the implementation of this plan. For example, numerous federal departments and agencies collaborate on issues of national scope and importance through the Joint Subcommittee on Aquaculture to effectively address issues related to aquaculture. The Department of the Interior and the Department of Commerce are the lead federal agencies responsible for coordination of aquatic nuisance species in the United States in collaboration with USDA and other agencies under the auspices of the Task Force.

**Strategy 3.7.1. Develop an implementation program that effectively coordinates, oversees, and drives implementation efforts.**

Implementation of this plan will require the sustained and dedicated efforts of numerous individuals to adequately coordinate and implement recommendations, seek funding, evaluate program success, and to modify strategies and recommendations based on lessons learned. This team should be comprised of a wide variety of individuals, representing agencies, organized interest groups, and individuals with appropriate expertise, to bring their collective experience and capabilities to bear on the issues. Agencies must allocate adequate staff support to this effort. The committee should be formalized to the degree necessary to clarify roles and responsibilities and to insure support of the agencies or partners involved. An effective implementation committee will turn recommendations into actions and will serve as a communication and coordination center for management and control of Asian carps.

**Recommendation 3.7.1.1. The Aquatic Nuisance Species Task Force should create a committee comprised of key partners and stakeholders with needed expertise to oversee the implementation of this plan.**

This recommendation is a critical first step to develop an effective implementation team and is best conducted under the oversight of the Task Force. This task should be accomplished quickly so that relevant programs and needed resources can contribute to implementation of this plan. The Working Group recommends the Task Force take immediate action to form this team upon approval of the plan and for the team to convene within 3 to 6 months. Implementation will be a national effort and will require flexibility by the team and by the individual agencies and stakeholders so that the needs of the team and the individuals are recognized and supported in a way that leads to coordinated and effective management and control of Asian carps.

**Recommendation 3.7.1.2. Develop institutional arrangements that formalize the roles and responsibilities of partner agencies and organizations in plan implementation.**

The purpose of an institutional arrangement is to formalize a process for government agencies and private stakeholders to work together. In this case, the common interest is the management and control of Asian carps. Formal institutional arrangements are essential for effectively coordinated and collaborative efforts, and for establishing decision-making processes among multiple entities and programs. Implementing an institutional arrangement framework can be challenging because it is often a change from the usual decision-making process. However, if this obstacle can be overcome, management decisions become integrated, science-driven, inclusive, efficient and cost-effective. A process for conflict resolution should be defined and agreed to during the development of institutional arrangements.

These institutional arrangements may be formalized through interagency agreements (e.g., Memoranda of Understanding or Agreement) among key governmental agencies as needed to foster communication, consultative processes, resource sharing, and information exchanges. While Memoranda of Understanding or Agreement are not always necessary for agencies and institutions to work together, they can help define and articulate responsibilities and expectations for all groups involved. These Memoranda are also an effective method to share resources and to exchange information.

Implementation of the Management and Control Plan requires a long-term commitment to the allocation of substantial human and financial resources. Institutional arrangements could require full-time employees to perform assigned tasks effectively. Regardless, management and control of four species of Asian carps in large river ecosystems, and at least three species with private commercial interest, will be very complex and will require substantial investment.

Establishing and agreeing on the details of institutional arrangements will be needed almost immediately after acceptance of this plan. Specifically, the agreement to establish the institutional arrangements will need to address: 1) what functions and thus what groups are needed, 2) who will comprise the groups, 3) who will chair the groups and for how long, 4) how the chairs will rotate, 5) how the groups will operate (consensus vs. majority), 6) to whom will the groups be accountable (e.g., Task Force, USFWS, USDA), and 7) the decision-making process and leadership hierarchy (if needed) for the groups constituting any institutional arrangements must be specifically outlined.

**Recommendation 3.7.1.3. Integrate, sequence, and prioritize recommendations from among all sections of this plan.**

This plan is organized into specific sections that address the primary issues of Asian carp control and management: 1) preventing accidental or deliberate unauthorized introductions, 2) containment, 3) population control, 4) minimize potential adverse effects, 5) education and outreach, 6) research, and 7) implementation. Additional efforts are needed to integrate, prioritize, and sequence projects across all sections of this plan. This plan contains a comprehensive list of recommendations, but not all recommendations can or should begin immediately. Many are building blocks that must be completed in the appropriate sequence. Also, the recommendations presented are very much interdependent. Management and control of Asian carps are not practical by just implementing selected recommendations. It is the combination of a suite of actions across the various sections of the program that will result in the desired effect.

Projects should be sorted relative to available funding. Lower priority projects that have funding should proceed, even if higher priority projects that lack funding must wait. Some recommendations may be put into action immediately given existing agency staff/funding or some redistribution of agency funds. Other recommendations will require “new” money that can be sought over the short-term but that may take some time for approval through agency budgeting processes. Actions that are high priority, properly sequenced, and can be completed with existing funds should be implemented immediately.

**Recommendation 3.7.1.4. Seek “new” funds from various sources to implement this plan.**

Funding is a critical component to fully address all components of this plan. The Working Group estimates the costs for implementation of all Recommendations (years 1-20) are approximately $286 million (see Table 4.1, page 115). Due to the large scope of projects to be undertaken in this plan, no single agency or institution will be able to provide the amount of funding needed to implement all elements of this plan. Even if agency budgeting processes are aligned with implementation of this plan, securing the needed funds will require special initiatives and efforts in new and different areas. This will be challenging with many competing interests for new funds. However, clear, accurate, and effective communication on the need to manage and control Asian carps, the potential threats that they pose, the array of recommendations identified, and the need for substantial and immediate funding will help to improve the probabilities for obtaining these funds.

Funding initiatives and support of budgetary planning for management and control of Asian carps are essential. <u>However, without new and bold funding initiatives, implementation of recommendations will be too slow and too limited to be effective.</u> Also, it will take time for federal and state agencies to incorporate new funding initiatives within their respective funding processes. Alternative sources may need to be investigated until the formal budgeting processes respond.

Given the many challenges, collaborative funding strategies will be needed. Development of cooperative funding agreements to optimize resources and secure funds for implementation should be considered. Cooperative Agreements are normally the preferred method to transfer funds, to share resources, and to exchange information. These are normally done on a case-by-case basis. However, a standard cooperative agreement could be developed to speed the process. The initial efforts to develop cooperative agreements will be the most challenging, but should become easier after initial efforts.

**Recommendation 3.7.1.5. Develop criteria and/or performance measures to evaluate the effectiveness of management and control efforts.**

For appropriate accountability of expenditures and to evaluate the effectiveness of management and control efforts, tools for assessing progress are needed. The first step will be to develop appropriate performance measures that can be tracked over time to monitor progress. Development of these performance measures should occur jointly with development of standardized sampling methodologies and a monitoring program so that methods used will provide the data needed for performance measures and so that performance measures developed are realistic given sampling/data limitations. Once developed, a program must be set in place to collect the appropriate data and to regularly develop progress reports.

**Recommendation 3.7.1.6. Develop an adaptive management framework that allows the flexibility to readily change and adapt management strategies as knowledge is gained and techniques are refined or developed.**

Our level of knowledge and experience in the management and control of Asian carps is somewhat limited. Ongoing and future research will answer many questions as will initial attempts at management and control. A strong adaptive management framework is needed to apply what we currently know, identify what else must be learned, and to adapt management strategies based on what is learned both through research and actions in the field. The framework must be designed for rapid incorporation of new information, particularly in the early stages of management and control so that managers can effectively prevent new introductions, stop the spread, and reduce or eradicate existing populations of Asian carps.

**Recommendation 3.7.1.7. Develop an effective strategy for communication and coordination among those implementing recommendations for management and control of Asian carps.**

An effective communication/coordination strategy and action plan is needed to enhance communications among stakeholders leading to timely exchanges of accurate information that is required to facilitate implementation of this plan. Without effective communication and coordination, the full potential of this plan cannot be achieved. The strategy should be inclusive and must outline efforts to communicate with the myriad audiences who are important for the success to this effort.

One tool to facilitate communication is a database of key institutional contacts that could be posted on the Internet. Agencies and institutions should identify their main points of contact for issues related to Asian carps and this plan. Identifying key agency and institutional contacts is a logical step to facilitate communications with the public and among agencies and institutions involved.

Another tool is the creation and maintenance of a web site (.gov) with pertinent information to facilitate the timely access and exchange of accurate information relative to the Working Group and implementation of this plan. The Internet has quickly become one of the most effective tools to communicate large amounts of information in a timely manner to large audiences. The need for centralized information collections and dissemination, communication tools, or web sites reoccurs throughout this plan. Creating and maintaining a single Internet web site to consolidate communication and coordination needs is crucial for implementation of this plan.

Development of peer-review procedures to ensure the scientific integrity and accurate reporting of information before broad circulation to the public is also needed. To help improve the quality of communication, a multidisciplinary ‘expert’ and communication’s team should be formed to evaluate the content of information, develop effective educational messages, and facilitate the sharing of information. The integrity and accuracy of information are very important. A peer-review process should be developed to achieve a highly respected scientific standard for information released.

While formal communications are important, we must also recognize the continued need for regular communications with partners and stakeholders, including face-to-face meetings, telephone, and electronic communications. These personal interactions cannot be replaced by more formal channels and procedures for communication.

# CHAPTER 4. TABLE OF RECOMMENDATIONS

Chapter 3 of the Management and Control Plan for Asian Carps in the United States is divided into 7 sections based on goals necessary to successfully address Asian carp issues: 1) prevent accidental and deliberate unauthorized introductions, 2) contain and control, 3) reduce abundance of feral populations, 4) minimize potential adverse effects, 5) education and outreach, 6) research, and 7) implementation. Strategies were developed to address each goal and numerous recommendations were developed to address each strategy. Table 4.1 is a compilation of the recommendations developed and a subjective estimate of the cost to independently implement each action.

Early in the implementation of this plan, efforts will be needed to integrate, prioritize, and sequence recommendations across all sections of this plan. This plan contains a comprehensive list of recommendations, but not all recommendations can or should begin immediately. Many are building blocks that must be completed in the appropriate sequence. The recommendations presented are very much interdependent. Management and control of Asian carps are neither practical nor effective by just implementing selected recommendations. It is the combination of the entire suite of actions across the various sections of the program that will result in the desired effect. Current priorities should be reassessed once integration and sequencing have been completed.

Funds to implement each recommendation were estimated as a starting point for further discussion and development. Costs for each recommendation were estimated independently; shared costs of some actions may reduce the total estimated costs for all recommendations. Full development of costs associated with each recommendation will not be possible without further exploration of recommendations; however, preliminary cost estimates were developed to begin to understand the scope of the management and control needs for Asian carps and to begin discussion of funding needs.

**Table 4.1.** Recommendations and estimated costs for management and control of Asian carps in the United States are presented by goal. Prioritization of recommendations across all goals is needed and should occur early in the implementation of this plan (Recommendation 3.7.1.3).

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[23] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| Goal 3.1 Prevention | 3.1.1.1. Assist states develop, promulgate, and enforce regulations that manage the harvest, transport, import, trade, and release of live wild-harvested aquatic bait. | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 500 |
| | 3.1.1.2. Develop and provide information to commercial and recreational baitfish harvesters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | B,BL,G,S | 50 | 50 | 25 | 25 | 25 | 250 |
| | 3.1.2.1. Encourage states to develop regulations that prohibit the stocking of any diploid Asian carps into non-aquaculture waters for biological control. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.2.2. Remove or contain diploid Asian carps that have been previously stocked into non-aquaculture waters for biological control. | B,BL,G,S | 2000 | 2000 | 2000 | 2000 | 2000 | 30000 |
| | 3.1.3.1. Encourage states that allow the legal importation of grass carp to adopt consistent, uniform regulations that allow only certified triploid grass carp to be shipped or stocked. | G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.3.2. Encourage states to conduct routine and random inspections of all live grass carp shipments within the state. | G | 1000 | 1000 | 1000 | 1000 | 1000 | 15000 |
| | 3.1.3.3. Encourage the USFWS to provide ploidy determination for states conducting inspections of grass carp shipments. | G | 300 | 100 | 100 | 100 | 100 | 1500 |

[23] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[24] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.5.1. Encourage states to prohibit stocking triploid bighead, black, and silver carps for biological control in non-aquaculture waters. | B,BL,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.5.2. Encourage states to allow stocking triploid grass carp for biological control in non-aquaculture waters only within watersheds where grass carp are already present in the wild. | G | 100 | 0 | 0 | 0 | 0 | 0 |
| | 3.1.5.3. Remove or contain triploid Asian carps that have been previously stocked in non-aquaculture waters within watersheds where the fish are not currently self-sustaining in the wild. | B,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.6.1. The USFWS should seek an independent scientific review and evaluation of the Triploid Grass Carp Inspection and Certification Program. | G | 100 | 0 | 0 | 0 | 0 | 0 |
| | 3.1.6.2. Develop and provide information on the USFWS Triploid Grass Carp Inspection and Certification Program. | G | 15 | 10 | 10 | 5 | 5 | 15 |
| | 3.1.7.1. Investigate fully the risks associated with ballast water transfers or other means of water transfer by barges and ships, and live well transfers by boats. | B,BL,G,S | 100 | 100 | 0 | 0 | 0 | 0 |
| | 3.1.7.2. Inform boaters, barge operators, and others of the risks of moving infested water and encourage voluntary actions to reduce this risk. | B,BL,G,S | 50 | 50 | 50 | 10 | 10 | 150 |

[24] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[25] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.8.1. Natural resources managers should employ pathway management tools, such as Hazard Analysis and Critical Control Point planning in the review of Standard Operating Procedures, to prevent introductions of Asian carps through natural resources management related pathways. | B,BL,G,S | 50 | 50 | 50 | 0 | 0 | 0 |
| | 3.1.8.2. Develop and provide information to natural resources managers and field staff that will help prevent unintentional introductions and spread of feral Asian carps. | B,BL,G,S | 50 | 50 | 10 | 10 | 10 | 100 |
| | 3.1.9.1. Prohibit international importation of Asian carps for non-commercial use under federal and state regulations, except for research purposes under a controlled permit. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.9.2. Inform USFWS Law Enforcement Officers, other federal inspectors, and state conservation law enforcement officers about laws that apply to the import of live Asian carps, the importance of preventing the illegal import of Asian carps, and Asian carp identification. | B,BL,G,S | 50 | 50 | 50 | 10 | 10 | 150 |
| | 3.1.9.3. Inform potential importers of applicable state and federal laws and associated risks with international shipments of live Asian carps. | B,BL,G,S | 50 | 50 | 50 | 10 | 10 | 150 |
| | 3.1.9.4. Increase the numbers of trained USFWS Law Enforcement Officers and increase physical inspections of international shipments of live fish and eggs at designated or non-designated ports of entry. | B,BL,G,S | 200 | 200 | 200 | 200 | 200 | 3000 |

[25] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[26] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.10.1. Develop federal and state regulations that prohibit importations of live bighead, black, grass, and silver carps for commercial use in the United States. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.12.1. Urge the development and enforcement of state regulations that prohibit the production of Asian carps at poorly sited facilities. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.12.2. Develop and provide information to Asian carp producers and growers that will help upgrade poorly sited facilities such that they are no longer high-risk to contain farm-raised carps and prevent accidental introductions. | B,BL,G,S | 100 | 100 | 50 | 50 | 25 | 250 |
| | 3.1.13.1. Form a coordinating research group that includes representatives from the aquaculture industry, the ethnic retail grocer industry, marketing scientists and developers, and aquaculture scientists to focus research efforts on the highest priority alternatives to the use of Asian carps. | B,BL,G,S | 100 | 100 | 50 | 50 | 25 | 250 |
| | 3.1.13.2. Develop an information module on economic and effective alternatives to replace the use of bighead and black carps on aquaculture facilities. | B,BL | 20 | 10 | 5 | 0 | 0 | 0 |
| | 3.1.14.1. Review Standard Operating Procedures and recommend Best Management Practices that include requirements for suppliers and purchasers to conduct inspections of fish prior to shipment and release. | B,BL,G | 50 | 0 | 0 | 0 | 0 | 0 |

[26] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[27] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.14.2. Encourage states to develop regulations that allow for random inspections of live fish shipments into and within the state. | B,BL,G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.14.3. Prohibit the use of surface waters containing Asian carps from being used in aquaculture facilities unless effective treatment is in place with a monitoring program. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.1. Review Standard Operating Procedures and develop Best Management Practices for "properly" sited aquaculture facilities. | B,BL,G | 50 | 0 | 0 | 0 | 0 | 0 |
| | 3.1.15.2. Encourage states to prohibit the use of grass carp on aquaculture facilities within watersheds where grass carp are not present in the wild. | G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.3. Encourage states to restrict the use of grass carp to certified triploids only on aquaculture facilities within watersheds where grass carp are present but not reproducing. | G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.4. States should encourage the use of only certified triploid grass carp on aquaculture facilities within watersheds where grass carp are self-sustaining in the wild. | G | 20 | 5 | 5 | 5 | 5 | 50 |
| | 3.1.15.5. Verify functional sterility of triploid bighead carp and develop a triploid certification program for bighead carp. | B | 100 | 50 | 50 | 0 | 0 | 0 |

[27] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[28] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.15.6. Encourage states to prohibit the use of bighead carp on aquaculture facilities within watersheds where bighead carp are not self-sustaining in the wild. | B | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.7. Encourage states to restrict the use of bighead carp on aquaculture facilities within watersheds with self-sustaining populations to certified triploids only. | B | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.8. Encourage states to prohibit the use and production of silver carp on aquaculture facilities. | S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.15.9. Encourage states to prohibit the use and production of diploid black carp on aquaculture facilities. | BL | 20 | 20 | 20 | 0 | 0 | 0 |
| | **3.1.15.10.** ***UNRESOLVED ISSUE:*** *Use of triploid black carp on aquaculture facilities.* | BL | 50 | 50 | 50 | 20 | 20 | 50 |
| | 3.1.16.1. Where legal for commercial or recreational fishers to possess Asian carps, encourage states to prohibit the possession of live wild-caught Asian carps. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.16.2. Review Standard Operating Procedures and actions of commercial fishers to identify Best Management Practices that reduce risks of live transport and introduction. | B,BL,G,S | 100 | 50 | 20 | 0 | 0 | 0 |

[28] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[29] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.16.3. Develop an information module and provide materials to commercial and recreational fishers and commercial live haulers that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | B,BL,G,S | 50 | 50 | 10 | 10 | 10 | 100 |
| | 3.1.17.1. Require informational labeling of truck and invoice for shipments of Asian carps to avoid improper handling and potential introduction of fish that may be involved in an accident (e.g., "Nonnative fish: Unauthorized release prohibited"). | B,G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.17.2. Review Standard Operating Procedures and develop Best Management Practices for fish haulers regarding containment and water transfer. | B,G | 50 | 0 | 0 | 0 | 0 | 0 |
| | 3.1.17.3. Prohibit the use of water from natural water bodies for water exchange during transport. | B,BL, G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.17.4. Investigate improvements for containment methods on trucks carrying Asian carps. | B,BL,G | 75 | 75 | 50 | 0 | 0 | 0 |
| | 3.1.17.5. Develop an information module and provide materials to commercial transporters of live farm-raised Asian carps that will help prevent accidental and deliberate unauthorized introductions. | B,BL,G,S | 75 | 75 | 50 | 50 | 250 | 250 |
| | **3.1.18.1.** ***UNRESOLVED ISSUE:*** *Commercial, domestic transport of live farm-raised bighead and grass carps.* | B,G | 50 | 50 | 20 | 20 | 20 | 50 |

[29] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[30] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.19.1. Encourage states to prohibit the sale, live transport, and unauthorized release of live Asian carps for non-commercial uses. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.19.2. Encourage states that allow sales of live Asian carps for human consumption to require retail grocers to kill the fish using prescribed humane methods, immediately upon sale. | B,G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.19.3. Use educational campaigns such as Habitattitude$_{TM}$ to convey messages to the public that they should not release live Asian carps. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.19.4. Develop an information module and provide materials to producers, growers, marketers, and foodfish consumers of live Asian carps that will help prevent accidental and deliberate unauthorized introductions. | B,G | 75 | 75 | 25 | 25 | 25 | 125 |
| | 3.1.20.1. Encourage states to prohibit the trade of Asian carps for aquaria and hobby purposes. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.21.1. Urge states to develop and enforce regulations to reduce risks associated with the possession and disposal of Asian carps for research and exhibition purposes. | B,G | 20 | 20 | 20 | 0 | 0 | 0 |
| | 3.1.21.2. Develop an information module and provide materials to the academic and research communities that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | B,BL,G,S | 75 | 75 | 25 | 25 | 25 | 250 |

[30] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[31] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.1.22.1. Develop an information module and provide materials to recreational fishers and boaters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | B,BL,G,S | 20 | 20 | 20 | 0 | 0 | 0 |
| Goal 3.2 Containment | 3.2.1.1. Develop a Decision Support System to assist natural resources managers in prioritizing specific locations for the construction, maintenance, monitoring, or removal of barriers to carp dispersal. | B,BL,G,S | 100 | 100 | 0 | 0 | 0 | 0 |
| | 3.2.1.2. Evaluate the effectiveness afforded by alternative technical containment measures (i.e., physical and behavioral barriers). | B,BL,G,S | 500 | 500 | 500 | 0 | 0 | 0 |
| | 3.2.1.3. Promote, support, and provide technical analysis and comment for the field testing of novel containment methods. | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 0 |
| | 3.2.1.4. Anticipate and address consequences of specific containment actions on native biological communities. | B,BL,G,S | 250 | 250 | 250 | 250 | 250 | 5000 |
| | 3.2.2.1. Develop and implement redundant barrier systems within the Chicago Sanitary and Ship Canal to limit the unrestricted access of Asian carps to Lake Michigan. | B,S | 3000 | 3000 | 3000 | 500 | 500 | 8000 |
| | 3.2.2.2. Develop and implement reasonable and effective measures that prevent the spread of Asian carps via canals, water ways, or other water diversions between basins. | B,BL,G,S | 2000 | 2000 | 1000 | 1000 | 1000 | 7500 |

[31] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[32] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.2.2.3. Construct and operate a Sound Projector Array-based acoustic bubble curtain fish deterrent at two locks and dams on the Upper Mississippi River to prevent the spread of Asian carps throughout the basin. | B,S | 12000 | 12000 | 250 | 250 | 250 | 4000 |
| | 3.2.2.4. Identify additional containment measures needed to limit intrabasin movements of feral populations of Asian carps within the Mississippi River and other basins where established. | B,BL,G,S | 0 | 100 | 100 | 0 | 0 | 0 |
| | 3.2.3.1. The USFWS and other natural resources management agencies should provide technical assistance and biological information to the USACE and participate in collaborative planning of fish passage structures. | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 1500 |
| | 3.2.3.2. Require federal and state agencies to consider the potential range expansion and ecological effects of Asian carps when designing or reviewing water control structure projects and permits. | B,BL,G,S | 25 | 25 | 25 | 25 | 25 | 375 |
| | 3.2.4.1. Develop an early detection Decision Support System to: 1) identify high risk locations susceptible to introductions or range expansions of Asian carps, 2) identify watersheds of special concern, 3) prioritize specific locations for implementing comprehensive early detection monitoring programs. | B,BL,G,S | 150 | 150 | 150 | 100 | 100 | 750 |

[32] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[33] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.2.4.2. Adopt and/or adapt an Incident Command System to provide for national coordination and management of early detection and rapid response programs. | B,BL,G,S | 250 | 250 | 250 | 250 | 250 | 3750 |
| | 3.2.4.3. Develop and conduct routine early detection monitoring programs in locations where risk of introductions or range expansions of Asian carps exists. | B,BL,G,S | 150 | 150 | 150 | 150 | 150 | 2250 |
| | 3.2.4.4. Develop Rapid Response Plans that identify where rapid response actions can effectively eradicate Asian carps and how those actions will be carried out. | B,BL,G,S | 150 | 150 | 150 | 0 | 0 | 0 |
| | 3.2.5.1. Develop a database and communication network with agencies that regulate Asian carp possession. | B,BL,G,S | 75 | 0 | 0 | 0 | 0 | 0 |
| | 3.2.5.2. Create an information sharing system with early detection monitoring and rapid response project managers. | B,BL,G,S | 75 | 0 | 0 | 0 | 0 | 0 |
| | 3.2.6.1. Develop a website and centralized databases to provide information on early detection and rapid response programs. | B,BL,G,S | 75 | 5 | 5 | 5 | 5 | 5 |
| | 3.2.6.2. Develop a list-server to provide a forum for information exchange. | B,BL,G,S | 5 | 5 | 5 | 5 | 5 | 5 |
| | 3.2.6.3. Utilize and support the Nonindigenous Aquatic Species Information Center for accurate and spatially referenced biogeographic information and the Nonindigenous Aquatic Species Alert System to track expansion. | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 15000 |

[33] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[34] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| Goal 3.3 Reduce Feral Populations | 3.3.1.1. Determine life history parameters of Asian carps in the Mississippi River Basin. | B,BL,G,S | 1000 | 1000 | 1000 | 1000 | 1000 | 300 |
| | 3.3.1.2. Create population, biomass, and recruitment models for Asian carps. | B,G,S | 120 | 120 | 120 | 120 | 120 | 30 |
| | 3.3.2.1. Evaluate gear and harvest method effectiveness, develop new gears if necessary, and provide information to commercial fishers. | B,S | 200 | 200 | 100 | 100 | 100 | 25 |
| | 3.3.2.2. Increase the number of commercial fishers. | B,S | 100 | 100 | 100 | 20 | 20 | 150 |
| | 3.3.2.3. Examine commercial fishing regulations and consider changes to increase harvest. | B,S | 30 | 30 | 30 | 0 | 0 | 0 |
| | 3.3.2.4. Provide financial incentives to commercial fishers to increase harvest of Asian carps. | B,S | 100 | 100 | 100 | 100 | 100 | 0 |
| | 3.3.2.5. Develop new markets for Asian carps. | B,G,S | 100 | 100 | 100 | 80 | 80 | 0 |
| | 3.3.2.6. Determine contaminant concentrations in edible portions of feral Asian carps. | B,G,S | 15 | 5 | 5 | 5 | 5 | 5 |
| | 3.3.3.1. Examine recreational harvest regulations to eliminate barriers to recreational harvest of Asian carps. | B,G,S | 20 | 20 | 0 | 0 | 0 | 0 |
| | 3.3.3.2. Inform recreational fishers about Asian carp harvest and preparation methods. | B,G,S | 25 | 25 | 15 | 5 | 5 | 5 |

[34] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[35] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.3.4.1. Develop information on the factors that determine the efficacy of native predator enhancement to control Asian carps. | B,S | 200 | 200 | 100 | 100 | 100 | 0 |
| | 3.3.5.1. Examine the potential efficacy of introduction of monosex tetraploid fish as a control method. | B,S | 400 | 400 | 400 | 400 | 400 | 200 |
| | 3.3.6.1. Adapt "daughterless carp" genetic technology to Asian carps. | B,S | 0 | 0 | 0 | 0 | 600 | 600 |
| | 3.3.7.1. Sex pheromone research should continue with the goal of production and application of field-applicable technologies. | B,S | 300 | 300 | 300 | 300 | 300 | 120 |
| | 3.3.7.2. Investigate aggregation pheromones for juvenile Asian carps. | B,S | 300 | 300 | 300 | 300 | 300 | 120 |
| | 3.3.8.1. Provide technical assistance and biological information to the USACE and participate in collaborative planning of habitat improvement projects (e.g., Navigation and Ecosystem Sustainability Program, Missouri River Mitigation Project, and other authorities). | B,S | 50 | 50 | 50 | 50 | 50 | 50 |
| | 3.3.9.1. Determine effectiveness of registered piscicides to control Asian carps. | B,BL,G,S | 180 | 180 | 180 | 180 | 180 | 60 |
| | 3.3.9.2. Identify conditions where rotenone or antimycin could be used to control populations of Asian carps. | B,BL,G,S | 180 | 180 | 180 | 180 | 20 | 20 |

[35] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[36] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.3.9.3. Determine potential of other chemicals to control Asian carps. | B,BL,G,S | 800 | 800 | 800 | 800 | 800 | 200 |
| | 3.3.9.4. Determine feasibility and applicability of piscicide bait deployment to control black and grass carps. | BL,G | 120 | 120 | 120 | 120 | 120 | 100 |
| | 3.3.9.5. Determine registration needs, if any, for the use of piscicides to control Asian carps, and ensure that piscicides are available for appropriate uses. | B,BL,G,S | 300 | 300 | 300 | 300 | 300 | 150 |
| Goal 3.4 Minimize Adverse Effects | 3.4.1.1. Monitor populations of species most likely to be affected by Asian carps. | B,BL,G,S | 500 | 500 | 500 | 500 | 500 | 500 |
| | 3.4.1.2. Restore or supplement numbers of native species through direct release (i.e., stocking). | B,BL,G,S | 50 | 50 | 50 | 50 | 50 | 20 |
| | 3.4.1.3. Protect or restore native species through methods other than stocking. | B,BL,G,S | 35 | 35 | 35 | 35 | 35 | 15 |
| | 3.4.2.1. Educate boaters to avoid damage from jumping silver carp. | S | 25 | 15 | 5 | 5 | 5 | 5 |
| Goal 3.5 Education & Outreach | 3.5.1.1. Engage potential key audiences in the development of a comprehensive education and outreach program. | B,BL,G,S | 60 | 15 | 15 | 15 | 15 | 225 |

[36] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[37] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.5.2.1. Develop an information module that defines and describes Asian carps, efforts to contain and reduce feral populations, and sources from which to learn more about these fishes. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| | 3.5.2.2. Develop an information module on the United States' Asian carp industry, size, scope, economics, and current farming practices. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| | 3.5.2.3. Develop an information module on potential effects of Asian carps and reasons to contain and reduce their feral populations. | B,BL,G,S | 60 | 0 | 0 | 0 | 0 | 0 |
| | 3.5.2.4. Develop an information module on the identification of all life stages of Asian carps. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| | 3.5.2.5. Develop an information module on why and how to report sightings of Asian carps. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| | 3.5.2.6. Develop an information module on Hazard Analysis and Critical Control Point planning procedures. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| | 3.5.2.7. Develop an information module on the construction and maintenance of effective spillway barriers to reduce the risk of escape of Asian carps from private impoundments. | B,BL,G | 60 | 5 | 5 | 5 | 5 | 75 |

[37] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[38] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.5.2.8. Develop an information module to provide general information about regulations related to Asian carps. | B,BL,G,S | 60 | 5 | 5 | 5 | 5 | 75 |
| Goal 3.6 Research | 3.6.1.1. Describe current and temporal changes in distribution to better understand the invasion and colonization process. | B, BL, S | 5000 | 5000 | 100 | 100 | 100 | 100 |
| | 3.6.1.2. Describe movements and distribution of Asian carps in waters of the United States (e.g., habitat preference, habitat selection, and habitats used). | B,BL,G,S | 5000 | 5000 | 100 | 100 | 100 | 100 |
| | 3.6.1.3. Describe diets, evaluate food selection and availability, estimate food consumption, and assess feeding interactions (i.e., predation and competition) with native biota (trophic ecology). | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 100 |
| | 3.6.1.4. Assess ecologically important aspects of physiology and behavior such as environmental tolerances, endocrine functions, and sensory capabilities. | B,BL,G,S | 500 | 100 | 100 | 100 | 100 | 100 |
| | 3.6.1.5. Estimate key population variables such as mortality, emigration and immigration, growth rates, fecundity, and stock-recruitment relations for population modeling. | B,BL,G,S | 500 | 500 | 100 | 100 | 100 | 100 |
| | 3.6.2.1. Develop and evaluate effective methods for sampling feral populations of Asian carps. | B,BL,G,S | 600 | 600 | 600 | 600 | 600 | 300 |
| | 3.6.2.2. Develop and evaluate effective attractants and repellents. | B,S | 250 | 250 | 250 | 250 | 250 | 1000 |

[38] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[39] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.6.2.3. Evaluate existing piscicides and, if necessary, develop new piscicides that are selective for Asian carps. | B, BL, S | 100 | 100 | 100 | 0 | 0 | 0 |
| | 3.6.2.4. Develop effective physical and behavioral barriers for controlling the movement of Asian carps. | B,BL,G,S | 5000 | 5000 | 5000 | 5000 | 5000 | 15000 |
| | 3.6.2.5. Evaluate the potential for commercial harvest of feral Asian carps to control their abundance in public waters. | B,BL,G,S | 100 | 100 | 100 | 100 | 100 | 100 |
| | 3.6.3.1. Assess the ecological effects of bighead, black, and silver carps on individual aquatic species and aquatic ecosystems. | B,BL, S | 500 | 500 | 500 | 500 | 500 | 500 |
| | 3.6.3.2. Document the actual ecological effects of bighead, black, grass, and silver carps. | B,BL, S | 500 | 500 | 500 | 500 | 500 | 500 |
| | 3.6.3.3. Conduct analyses of economic effects. | B,BL,G,S | 500 | 500 | 100 | 100 | 50 | 50 |
| | 3.6.4.1. Evaluate ecologically safe and economically viable alternatives to black carp for snail control. | BL | 500 | 500 | 500 | 500 | 500 | 500 |
| | 3.6.4.2. Characterize ethnic markets for live fish and for fresh fish on ice. Determine consumer preferences for various attributes including size, product form, and price. | B,BL,G,S | 250 | 250 | 100 | 100 | 100 | 100 |

[39] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[40] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.6.4.3. Evaluate the economic feasibility of growing and selling triploid bighead and grass carps for the live and fresh-on-ice markets. | B,G | 75 | 75 | 0 | 0 | 0 | 0 |
| Goal 3.7 Implementation | 3.7.1.1. The Aquatic Nuisance Species Task Force should create a committee comprised of key partners and stakeholders with needed expertise and identify a lead agency to oversee the implementation of this plan. | B,BL,G,S | 50 | 0 | 0 | 0 | 0 | 0 |
| | 3.7.1.2. Develop institutional arrangements that formalize the roles and responsibilities of partner agencies and organizations in plan implementation. | B,BL,G,S | 50 | 0 | 0 | 0 | 0 | 0 |
| | 3.7.1.3. Integrate, sequence, and prioritize recommendations from among all sections of this plan. | B,BL,G,S | 50 | 50 | 0 | 0 | 0 | 0 |
| | 3.7.1.4. Seek “new” funds from various sources to implement this plan. | B,BL,G,S | 50 | 0 | 0 | 0 | 0 | 0 |
| | 3.7.1.5. Develop criteria and/or performance measures to evaluate the effectiveness of management and control efforts. | B,BL,G,S | 100 | 100 | 0 | 0 | 0 | 0 |
| | 3.7.1.6. Develop an adaptive management framework that allows the flexibility to readily change and adapt management strategies as knowledge is gained and techniques are refined or developed. | B,BL,G,S | 25 | 50 | 50 | 50 | 50 | 750 |

[40] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

**Table 4.1.** Continued.

| Recommendations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Goal | Recommendation | Species[41] | Estimated Funding in Thousands by Year | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6-20 |
| | 3.7.1.7. Develop an effective strategy for communication and coordination among those implementing recommendations for management and control of Asian carps. | B,BL,G,S | 25 | 100 | 10 | 10 | 10 | 150 |

[41] B = bighead carp, BL = black carp, G = grass carp, S = silver carp

# CHAPTER 5. LITERATURE CITED

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# CHAPTER 6. APPENDICES

## Appendix 6.1. Drafting Team Members

### Prevention Drafting Team

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[1] Team lead for first draft
[2] Team lead for revisions to first draft

# Appendix 6.2. Summary of Asian Carp Working Group Decisions for Developing Recommendations to Prevent Unauthorized Introductions of Asian Carps (Nashville, Tennessee, August 22-25, 2005).

- **Need to develop and share a common big picture perspective**

  "Goal:" no AC in the wild, with exception of sterile grass carp within planned locations only

  - non-reproducing grass carp may be used in targeted, controlled locations, as part of an aquatic vegetation management plan. (Managed use includes appropriate risk analysis and/or planning.)
  - <u>nobody</u> wants to see <u>unintentional</u> introductions into the wild
  - need to deal with ramifications of "no" in the statement…does it lead to 100% prevention or allow some room for risk
  - feral (fish in non-target, unplanned areas) populations (reproducing or otherwise) of all AC are a continued risk for spread; active controls are needed in "high risk" situations (not warranted in all situations due to low risk and/or high costs) and must be balanced with effects of control efforts on natives.
  - domestic stocks of AC (which species?) warrant a framework under which these species can be used responsibly (managed risk?) as this is one of many potential pathways
  - prevention efforts must be prioritized using a variety of factors (matrix), such as relative risk (chance of occurring and effect if it occurs) and resource affected – for example:

    1) uninvaded waters – new basins (Great Lakes, East Coast, etc.)

    2) uninvaded waters of high resource value within an invaded basin (need to know rate of invasion and what is an "uninvaded" water)

    3) additional introductions into existing range
  - Need to address issues such as ploidy, live transport, and live sales for each species individually

**Grass carp**

- Literature supports that triploidy produces functionally sterile grass carp
- Effectiveness of triploidy for protecting natural resources is dependent upon effectiveness of inspection and certification programs
- Must use other control measures for redundancy when opting to use triploidy, e.g. locking lids, improved latches, hazard labeling, rotenone on rollover, etc.

| **Location** | **Grass Carp – Natural Resources – Biocontrol (farm ponds, lakes, etc.)**<br><br>**Recommendation** |
|---|---|
| Grass carp completely absent (e.g. Alaska) | No grass carp.<br><br>States must carefully consider using grass carp. If decide to use grass carp, then should only use certified triploids with appropriate controls for containment. |
| Grass carp present, but no evidence of reproducing population. | Certified triploid only |
| Self-sustaining grass carp population | Certified triploid only<br><br>Note: There needs to be acknowledgment about the potential impact to small farm pond owners. There may be a financial impact by switching to triploids. Estimate of $2/fish or $20/acre. |

| Location | Grass Carp – Aquaculture – Biocontrol and food fish production<br>Recommendation |
|---|---|
| Grass carp completely absent (e.g. Alaska) | No grass carp.<br>States must carefully consider using grass carp. If decide to use grass carp, then should only use certified triploids with appropriate controls for containment. |
| Grass carp present, but no evidence of reproducing population. | Certified triploid only |
| Self-sustaining grass carp population | Certified triploid only<br>Allow diploids if adequate and redundant containment controls in place. |

| Location of Live Transport | Grass Carp – Live transport and sales as food fish<br>Recommendation |
|---|---|
| Grass carp completely absent (e.g. Alaska) | No live transport or live fish sales.<br>States must carefully consider allowing live grass carp. If decide to allow live grass carp, then should only allow certified triploids and require killing fish at point of sale.<br>Dissenting opinion: Should allow diploids if they are transported with adequate controls and killed at point of sale. Need to understand the economic effect to industry by switching to triploid production for food fish sales. Industry needs 4 years to phase out diploids. |
| Grass carp present, but no evidence of reproducing population. | Certified triploid only; kill fish at point of sale?<br>Same dissenting opinion. |
| Self-sustaining grass carp population | Certified triploid only; kill fish at point of sale?<br>Same dissenting opinion. |

**Bighead carp**

- Raising triploids will cost producers more money, not certain if economically feasible.
- Research needed to verify the sterility of triploid bighead carp; not certain if 100% sterile
- If functionally sterile, a triploid bighead carp inspection and certification program would be needed. There was some discussion that the FWS should expand its triploid grass carp certification program to include bighead carp.
- Recommendation for triploids dependent upon research to determine if triploid bighead carp are functionally sterile and the establishment of an effective triploid inspection and certification program in place.
- Effectiveness of triploidy is dependent upon effectiveness of inspection and certification programs
- Must use other control measures for redundancy when opting to use triploidy, e.g. locking lids, improved latches, hazard labeling, rotenone on rollover, etc.

| **Location** | **Bighead Carp – Bio-control for aquaculture Recommendation** |
|---|---|
| Bighead carp completely absent | No bighead carp.<br>Triploid, if state allows, but state must manage risk through adequate and redundant controls. |
| Bighead carp present, but no evidence of reproducing population. | No bighead carp.<br>Triploid, if state allows, but state must manage risk through adequate and redundant controls. |
| Self-sustaining bighead carp population | Triploid<br>Diploid, only if farm has adequate and redundant controls. |

| Location of Live Transport | Bighead Carp – Live transport and sales as food fish<br><br>Recommendation |
|---|---|
| Bighead carp completely absent | No live transport or live fish sales.<br><br>States must carefully consider allowing live grass carp. If decide to allow live grass carp, then should only allow certified triploids and requiring killing fish at point of sale.<br><br>Dissenting opinion: Should allow diploids if they are transported with adequate controls and killed at point of sale. Need to understand the economic effect to industry by switching to triploid production for food fish sales. Industry needs 4 years to phase out diploids. |
| Bighead carp present, but no evidence of reproducing population. | Certified triploids only and require killing of fish at point of sale.<br><br>Same dissenting opinion. |
| Self-sustaining bighead carp population | Certified triploids only and require killing of fish at point of sale.<br><br>Same dissenting opinion. |

**Black carp**

- Common goal is no black carp but different views on how long to reach that goal
- Research needed to verify the functional sterility of triploid black carp
- If functionally sterile, a triploid black carp inspection and certification program would be needed. There was some discussion that the FWS should expand its triploid grass carp certification program to include black carp with 100% of fish inspected (retested).
- Recommendation for triploids is dependent upon research to determine if triploid black carp are functionally sterile, the establishment of an effective triploid inspection and certification program, and redundant containment measures.
- Effectiveness of triploidy for protecting natural resources is dependent upon effectiveness of inspection and certification programs and effectiveness of containment measures
- Must use redundant control measures when opting to use triploid black carp
- Consider individual/batch tagging for purpose of identifying and correcting escapes
- Research needed to find alternatives to black carp for snail control

| Location | Black Carp – Aquaculture Bio-control Recommendation |
|---|---|
| AC completely absent (all states except for AR, MS, MO) | No black carp<br>Dissenting opinion: Black carp will continue to be needed as there is no alternative; some states (Florida, Alabama) may still want black carp in their tool kit |
| AC introduced, but no evidence of reproducing population. (AR, MS, MO) | Common desired endpoint – no black carp, but given lack of alternatives recommend limited use of certified triploids with redundant controls for containment<br>Note – concurrent research for alternatives paramount<br>Dissenting opinion: Triploid black carp are too high risk to imperiled mollusks and are not an acceptable alternative; individual black carp can negatively effect imperiled mollusks; black carp should be immediately phased out and all stakeholders should work together to seek alternatives (including short-term subsidies if necessary). |

**Silver carp**

- Currently no commercial interest
- Recommend no production, no live haul, no live sales
- Recommend possession of live silver carp be prohibited

# Appendix 6.3. Overview of Physical and Behavioral Barriers

## Behavioral Technologies

**Acoustic Barriers or Deterrents:** Fish vary in their sensitivity to underwater sound, which will clearly influence the potential efficacy of an acoustic barrier. Asian carp species are known to be sensitive to sound. Fish size is also an important factor in relation to acoustic deterrence efficiency. Observations have confirmed that smaller sized fish may be more tolerant and could require stronger, higher frequency sound in order to be effective.

Acoustic barriers have shown promise in research trials. Bighead and silver carps have acute hearing and are sensitive to frequencies outside the range of many native species. Thus, an acoustic array could be designed such that it primarily affects bighead and silver carps and has less effect on non-target species.

**Bubble Curtain:** The bubble curtain is the most elementary form of behavioral fish barrier, which in its simplest form consists of a perforated tube laid across a river bed through which compressed air is forced. The rising curtain forms a wall of bubbles that can deflect fish. Efficacy of the bubble curtain may be enhanced when combined with light or sound.

**Electrical Barriers or Deterrents:** The electrical fish barrier or deterrent can function either as an impassable barricade or as a fish guidance system. In either case, the system consists of a series of metal electrodes submersed in water to create an electrical field capable of repelling fish.

Electrical barriers have been evaluated for preventing the expansion of feral Asian carp populations in both the Chicago Sanitary and Ship Canal and the Upper Mississippi River System. While considered feasible for the Chicago Sanitary and Ship Canal, it was determined that electrical barriers would be less effective and less feasible on the Upper Mississippi River System (FishPro 2004). Although currently in use, electric barriers are not the end-all solution to the range expansion of feral Asian carps in the United States. Electric barriers are not selective as to species affected. The electric field affects all species and sizes of fish to varying degrees. Large fish are more susceptible to the electric field than small fish and some species of fish are more sensitive to the presence of the field. Since the barrier relies on the ability of organisms to respond and move away form the discomfort caused by the electrical current, organisms unable to swim against the water flow will be carried through the electrical field. Asian carp are approaching the barrier from downstream, therefore the eggs and larvae of these species would be flushed away from the barrier (personal communication, Phil Moy, University of Wisconsin – Sea Grant). Corrosion of the electrodes reduces their effectiveness over time, so these components will require replacement. As such, electric barriers should be viewed as one component of a near-term approach for Asian carp containment.

**High Pressure Sodium and Mercury Lights:** High pressure sodium lights (1,000 watts) have been used to attract and hold fish to slow water areas located near a powerhouse spillway. Mercury lights have also been used as attractants for species-specific applications. Attractants may be used in combination to congregate fish that are avoiding other behavioral barriers or deterrents.

**Hydrodynamic Louver Screens:** Hydrodynamic louver screens are basically fins angled to the flow direction that are structurally supported in panels across the channel. Although a structure, the louvers cause a velocity increase that would repel some fish. They would generate a head to produce the increased velocity, would require a uniform channel, and are species and size specific for a given flow.

**Pheromones:** Research on pheromones, either alarm substances or attractants for spawning aggregation, is underway but is in the early stages of development for Asian carps. These species-specific substances hold promise as a powerful tool in preventing Asian carp expansion and in Asian carp population management.

**Strobe light:** The strobe light has been extensively evaluated as a fish deterrent in both laboratory and field situations and has been used in conjunction with other behavioral devices to increase the level of fish diversion. Combinations with bubble curtains may enhance the effectiveness of both, as the light can be projected onto the bubble sheet. Strobe lights can repel fish by producing an avoidance response.

## Physical Technologies

**Vertical drop:** The vertical drop barrier is basically an overflow weir as a component of a dam, which would provide a hydraulic drop over the structure higher than the leaping ability of the target species. Spatial geometry of the downstream pool would incorporate the consideration of creating hydraulic conditions that would prevent good staging behavior of the fish, prior to the jump, from occurring.

**Rotating drum screens:** Rotating drum screens continuously rotate to pass debris over the top of the drum to the downstream side, where flow through the screen can carry it away. A set of drum screens could be oriented perpendicular to or at a slight angle to the flow, depending on the site configuration. Provisions are typically made for lifting individual drums out for maintenance. Rotating drum screens are well-proven systems for smaller applications under the proper conditions. Because wetted screen elements are constantly exposed to air, drum screens will not function in severely cold weather with a completely enclosed structure above the water surface. Sizing screens to accommodate downstream passage is not practical.

**Traveling screens:** Traveling screens have been most commonly used in the past for smaller river diversion barriers. The unit would rotate continuously, lifting debris over the top and depositing it on the downstream side, similar to the rotating drum concept. As with the rotating drum, continuous exposure to wetted elements would make cold weather operation difficult or impossible without a completely enclosed structure above the water surface. Traveling screens would be subject to the same approach velocity and surface area requirements as for a stationary, or rotating self-cleaning screen, and would also appear impractical for use on Upper Mississippi River locks and dams.

**Floating curtains:** Floating curtain systems generally consist of a piling or float supported cable with nylon nets or hanging chains attached. Using nets or hanging chains as a barrier for major structures on the Upper Mississippi River with the high water velocities, substantial depths and debris loading would not be practical. There may, however, be a possibility to use smaller floating barriers to guide fish to a control area.

**High velocity barriers:** High velocity barriers are commonly configured as a flat apron below or part of a dam spillway, which generally has a high water velocity at variable flows. The velocity of the water must exceed the burst, or by distance, the sustained swimming speed of the target species. While these high velocity barriers may not be feasible or practical for the Upper Mississippi River, there may be potential for consideration on smaller tributary scale applications.

**Table 6.3.** Summary of potential alternatives to limit the invasion of Asian carps. Table courtesy of FishPro 2004.

| Control Method | Type of Alternative | Optimum Diversion Efficiency[1] | Probable Risk of Failure | Navigational Effect | Construction and/or Implementation Complexity | Operational and/or Maintenance Issues | Public Safety Concerns | Comments |
|---|---|---|---|---|---|---|---|---|
| Behavioral Barriers and Deterrents | Strobe Lights | ~50 - 95% | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.) | None to minimal | Moderate: Packaged unit | Low: Lamp and power delivery system maintenance | None | Only considered to be appropriate as a lock entrance channel deterrent |
| | Air Bubble Curtain | ~50 - 95% | High: Does not work in high water velocity and turbulence | None to minimal | Moderate: Air piping in varying depths | Moderate : Compressor and air line maintenance | None | Only considered to be appropriate as a lock entrance channel deterrent. Not effective under high flow conditions. |
| | Acoustic Deterrent: Sound Projector Array (SPA) at Lock Entrance | ~60 - 90% | Moderate to High : Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.) | None to minimal | Moderate: Packaged unit | Low : Transducer and power delivery system maintenance | None | Potentially feasible as a deterrent for lock entrance channels |
| | Acoustic Deterrent: Sound Projector Array (SPA) at Spillway gates | ~60 - 90% | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.) | None to minimal | Moderate: Packaged unit | Low: Transducer and power delivery system maintenance | None | Potentially feasible as a deterrent for spillway gate areas opened under full flow conditions |

[1] Optimum efficiency ranges obtained from existing references in literature for species specific case studies, site specific installations and reported field-test results. Actual diversion efficiencies may vary according to site conditions and species targeted for deterrence.

**Table 6.3.** Continued.

| Control Method | Type of Alternative | Optimum Diversion Efficiency[1] | Probable Risk of Failure | Navigational Effect | Construction and/or Implementation Complexity | Operational and/or Maintenance Issues | Public Safety Concerns | Comments |
|---|---|---|---|---|---|---|---|---|
| | Acoustic Deterrent: Pneumatic Acoustic Bubble Curtain (BAFF) at Lock Entrance | ~60 - 90% | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.); does not work in high water velocity | None to minimal | Moderate: Packaged unit; air piping in varying depths | Low: Transducer and power delivery system maintenance; compressor and air line maintenance | None | Potentially feasible as a deterrent for lock entrance channels |
| | Acoustic Deterrent: SPA Based Acoustic Bubble Curtain (SPA/BAFF) at Lock Entrance | ~90%+ | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.); does not work in high water velocity; enhances the overall effectiveness of a standard BAFF in areas with intermittent turbulence and barge traffic. | None to minimal | Moderate: Packaged unit; air piping in varying depths | Low: Transducer and power delivery system maintenance | None | Potentially feasible as a deterrent for lock entrance channels. Enhances the overall effectiveness of a standard BAFF system; SPA component allows utilization of Asian carp specific audiogram. |
| | Hybrid Comb. System (Strobe light/acoustic) | ~60 - 95% | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.) | None to minimal | Moderate: Packaged unit | Low: Transducer and power delivery system maintenance | None | Potentially feasible as a deterrent for lock entrance channels. Combination systems have generally proven to be more effective |
| | Hybrid Comb. System (Str. light/bubble curt.) | ~60 - 95% | Moderate to High: Species and size specific; location & day/night specific; effectiveness varies with time of year (water temperature, flow, etc.); does not work in high water velocity | None to minimal | Moderate: Packaged unit; air piping in varying depths | Moderate: Compressor, air line and power delivery system maintenance | None | Potentially feasible as a deterrent for lock entrance channels. Combination systems have generally proven to be more effective |

[1] Optimum efficiency ranges obtained from existing references in literature for species specific case studies, site specific installations and reported field-test results. Actual diversion efficiencies may vary according to site conditions and species targeted for deterrence.

**Table 6.3.** Continued.

| Control Method | Type of Alternative | Optimum Diversion Efficiency[1] | Probable Risk of Failure | Navigational Effect | Construction and/or Implementation Complexity | Operational and/or Maintenance Issues | Public Safety Concerns | Comments |
|---|---|---|---|---|---|---|---|---|
| | Electrical Barrier (Main stem or at spillway gates/culverts) | ~90 - 99% | Moderate: Variable depth for electrical field, silt, maintenance, size dependent | None to minimal | High: Electrode installation in water | High Power outages, maintenance, debris, etc. | High: Safety issues; negative Perception | Technically feasible for a large main stem river installation. Significant power requirement and public safety concerns. |
| | Electrical Barrier (Inside Lock) | ~90 - 99% | Moderate: Variable depth for electrical field, silt, maintenance, size dependent | None to minimal | High: Electrode installation in water | High: Safety | High: Safety issues; negative Perception | Technically feasible for a large main stem river installation. Significant power requirement and public safety concerns. |
| | Electrical Deterrent (Lock Channel Entr.) | ~90 - 99% | Moderate: Variable depth for electrical field, silt, maintenance, size dependent | None to minimal | High: Electrode installation in water | High: Safety | High: Safety issues; negative Perception | Technically feasible for a large main stem river installation. Significant power requirement and public safety concerns. |
| | Hyb.Comb. System (Electric Barrier & SPA/BAFF) at Lock | ~90 - 99% | Moderate: Variable depth for electrical field, silt, maintenance, size dependent | None to minimal | High: Electrode installation in water | High: Safety | High: Safety issues; negative Perception | Technically feasible for a large main stem river installation. Significant power requirement and public safety concerns. |
| | Hydrodynamic Louver Screens | ~86 - 97% | High: Fouling problems; species and size specific | Significant | Moderate : Anchor system in water | High: Icing and fouling by debris | Slight to Moderate | Not a suitable technology due to navigational effect, high maintenance requirement and a tendency to clog with silt and debris |

[1] Optimum efficiency ranges obtained from existing references in literature for species specific case studies, site specific installations and reported field-test results. Actual diversion efficiencies may vary according to site conditions and species targeted for deterrence.

**Table 6.3.** Continued.

| Control Method | Type of Alternative | Optimum Diversion Efficiency[1] | Probable Risk of Failure | Navigational Effect | Construction and/or Implementation Complexity | Operational and/or Maintenance Issues | Public Safety Concerns | Comments |
|---|---|---|---|---|---|---|---|---|
| Physical Barriers | Vertical Drop (Existing Overflow Spillways) | ~95 - 100% | Low: Site dependent | Significant at spillway; Access through locks | Site dependent | Low | Existing Spillway | Locating a barrier or deterrent system at an existing lock and dam with a high head spillway can provide partial barrier benefits. |
| | Rotating Drum &/or Traveling Screens, Floating Curtains | ~95 - 100% | Low to Medium | Significant Effect at locks | Extreme: Extensive civil works; Cofferdams | High: Icing; Fouling | Varying; not applicable | Physical barrier alternatives not considered to be practical or feasible for the UMR due to magnitude of installation and/or navigational requirements |
| | High Velocity (Point Release) | Unknown; species specific | Low: Site dependent | None if installed at spillway gates | Site and species dependent | Moderate; debris may clog or damage | Unknown Site dependent | Although potentially retrofitted into an existing lock and dam spillway, swimming capabilities of Asian carps may preclude feasibility |

[1] Optimum efficiency ranges obtained from existing references in literature for species specific case studies, site specific installations and reported field-test results. Actual diversion efficiencies may vary according to site conditions and species targeted for deterrence.

# Appendix 6.4. Additional Information on the Chicago Sanitary and Ship Canal

The City of Chicago was established in its present location because of the site's advantages in gaining navigational access between the Great Lakes and the Mississippi River. The 28 mile long Chicago Sanitary and Ship Canal reversed the flow of the Chicago River in 1900 by linking the South Branch of the Chicago River with the Des Plaines River (Chicago Historical Society 2005). The canal, which was designed both as a transportation route and a means to improve water quality by sending Chicago's sewage south into the Illinois River instead of into Lake Michigan, connected the two ecosystems with a continuous flow of water. To accommodate developing navigation demands, the Calumet River was joined to the Chicago Sanitary and Ship Canal via the Cal-Sag Channel and the Chicago River Locks and Controlling Works, the T.J. O'Brien Lock and Dam, and the Indiana Harbor Canal were constructed (Figure 6.4).

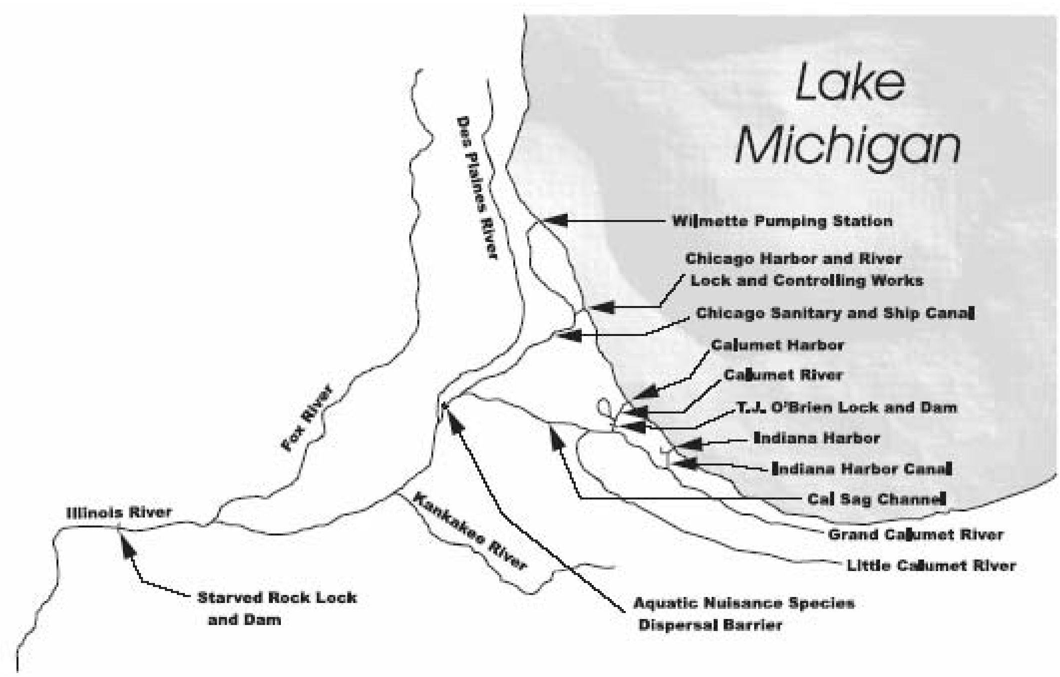


**Figure 6.4.** Map of the Cal-Sag and Chicago Sanitary and Ship Canal and its connections to Lake Michigan and the Illinois River. Figure courtesy of Jerry Rasmussen, USFWS.

Prior to enactment and implementation of the Clean Water Act, the canal was severely polluted with both domestic and industrial wastes (Rasmussen 2001). As a result dissolved oxygen levels in canal waters were depleted and aerobic organisms could not survive, thus creating a chemical barrier to movement of freshwater organisms between the two ecosystems. However, as technology developed and waste treatment methods improved, the Metropolitan Reclamation District of Greater Chicago did a marvelous job cleaning up the city's wastes and increasing dissolved oxygen levels in canal waters to the point that freshwater organisms now thrive in the canal (Rasmussen 2001).

Unfortunately, a byproduct of this success is the fact that the canal now provides an artificial gateway between these two ecosystems and serves as a viable pathway for nuisance species infestations (Rasmussen 2001). The biological results can be seen in the growing exchange of organisms between the two ecosystems [e.g., zebra mussels, white perch (*Morone americana*), round goby (*Neogobius melanostomus*)]. Zebra mussels, which have spread throughout the Great Lakes and the Mississippi and Hudson River basins, have had a number of negative ecological and economic effects (MIT Sea Grant 2002). Zebra mussels are expected to cost the United States $5 billion in control efforts and reparation (MIT Sea Grant 2002). They have displaced native freshwater mussels of the area and drastically altered the food web (MIT Sea Grant 2002). Asian carps threaten to invade the Great Lakes via the same pathway, with potentially similar results. Recently, bighead carp have been collected within 50 miles of Lake Michigan, and the Chicago Sanitary and Ship Canal is the primary key to stopping large numbers of these nuisance fishes from reaching Lake Michigan and the other Great Lakes.

The National Invasive Species Act of 1996 authorized the USACE to investigate the potential for implementing a dispersal barrier to prevent the spread of aquatic nuisance species via the Chicago Sanitary and Ship Canal. After considering the range of options available, the multi-agency Dispersal Barrier Advisory Panel recommended using an electrical barrier as the first step in the development of the project. An electrical barrier was perceived to have the fewest permitting and safety issues. The technology was commercially available and the members agreed that the approach had a high likelihood of being effective on fish. Though the original target organism was Eurasian ruffe (*Gymnocephalus cernuus*), focus soon turned to the round goby which appeared in Calumet Harbor in the mid 1990's. Unfortunately, due to funding and construction delays the round goby expanded its range beyond the barrier site before construction could begin. Today, the focus of barrier development is on stopping the spread of Asian carps into the Great Lakes.

Kolar and Lodge (2002) developed predictive models to assess the risk to the Great Lakes from introduced fishes. The models predict that black carp would not become established in the Great Lakes if introduced and that silver carp could become established, but would neither spread quickly nor be perceived as a nuisance in the Great Lakes. The authors caution that model predictions about these two fishes "should be interpreted with caution [because] these species exhibit characteristics that differ substantially from those of species on which the models were developed, and our models may not be robust to such deviations." In addition, the model "predictions are applicable to the Great Lakes proper, not to tributaries and large river systems in which these carp species … are already established [outside the Great Lakes] and causing strongly negative consequences." Access to rivers with 100km or more of undammed flowing water are required for successful reproduction and will play a large role in determining the potential range of bighead, black, and silver carps (Kolar et al. 2005; Nico et al. 2005). Kolar et al. (2005) identified 22 tributary rivers to Lakes Erie, Huron, Michigan, and Superior that could potentially serve as spawning sites for bighead and silver carps. These same rivers could potentially serve as spawning sites for black and grass carps, which have similar spawning requirements to bighead and silver carps (Nico et al. 2005).

# Appendix 6.5. Additional Information on Acoustic Dispersal Barriers

When considering audible range frequencies, hearing sensitivity is determined by the presence or absence of a swim bladder and by any anatomical specializations that improve the conduction of sound from the swim bladder to the inner ear (Hawkins 1981). Fish size is also an important factor in relation to acoustic deterrence efficiency.

Deflection is the most effective action for an acoustic deterrent system, where the fish are diverted away from a structure and into a targeted area. Blocking such as a barrier perpendicular to river flow can be more difficult if the fish are not diverted away from the protected area because the risk of habituation to the sound signal increases. The ideal sound field should form a steep acoustic gradient approaching the entrance, free from acoustic nulls (voids) caused by destructive interference within the sound field. The presence of such nulls could cause fish to be guided into instead of away from the river structure.

A Sound Projector Array (SPA) low frequency acoustic deflection system consists of an electronic signal generator, one or more power amplifiers and an array of underwater sound projectors. The Sound Projector Array system uses underwater sound projectors powered by audio amplifiers and electronic signal generators to create a repellant field ahead of a structure. Annual maintenance requirement involves removing the underwater units to check moving components and repair if necessary.

The disadvantage of a Sound Projector Array is that the sound is not concentrated as with a Bio-Acoustic Fish Fence (BAFF, introduced below). A Sound Projector Array is more suited to covering an opening or intake where there is a flow past the opening and the Sound Projector Array system pushes the fish away from the opening and into the main flow of the river, as an example. In applications, where it is necessary to deflect fish swimming 'head long' into the barrier, a higher and more concentrated sound field (as in a Bio-Acoustic Fish Fence) is required to deflect the fish.

The Bio-Acoustic Fish Fence is a proprietary product that uses a combination of a sound source and a bubble curtain to create a field that is largely contained within the bubble sheet. Physically, the system consists of an electromagnetic or pneumatic sound transducer coupled to a bubble-sheet generator, causing sound waves to propagate within the rising curtain of bubbles.

Operating costs for a Bio-Acoustic Fish Fence generally are higher than for an equivalent Sound Projector Array system, because it requires an air blower or compressor. However, the compressed air demand is less than an equivalent stand-alone bubble curtain system because a smaller volume of air is typically required. The Bio-Acoustic Fish Fence is typically used to divert fish from a particular flow area and may be regarded as analogous to a conventional angled fish screen. It utilizes an air bubble curtain to contain a sound signal through refraction that essentially becomes a “wall of sound” (an evanescent sound field) that can guide fish around and /or away from river structures. The sound level inside the bubble curtain may be as high as 170 dB and decaying to as much as 5% of this value within 0.5 to 1.0 meters away from the bubble curtain. The disadvantage of the conventional Bio-Acoustic Fish Fence is that it is less capable of being tailored directly to the audiogram of the carp (depending on the audiogram frequencies) than the Sound Projector Array system.

A hybrid system has been developed recently by Fish Guidance Systems (FGS) that utilizes the Sound Projector Array-based sound projection system coupled with an air driven bubble curtain. This system differs from the conventional Bio-Acoustic Fish Fence system in that the Sound Projector Array projectors can be calibrated to produce a sound signal that matches a particular fish deterrent audiogram, whereas the pneumatically driven sound source of the conventional Bio-Acoustic Fish Fence system cannot. In addition to the enhanced sound calibration capability, the omni-directional sound projectors would couple with the bubble curtain as a focus medium for the sound projection.

A conventional Bio-Acoustic Fish Fence has an audio driver unit that produces the sound pneumatically, directly into the air supply for the bubble curtain, so in a conventional “pneumatic Bio-Acoustic Fish Fence” the sound is contained within the bubbles at very high sound levels. The sound drops off very quickly from the bubble curtain, which makes it ideal for guiding fish. With a Sound Projector Array, the sound field is more widespread, but acoustic modeling would ensure that a smooth even sound field is produced from a Sound Projector Array-based system.

The hybrid Sound Projector Array driven Bio-Acoustic Fish Fence has an advantage over either conventional system since it combines both the ease of signal selection of an Sound Projector Array, and the concentrated sound field of a Bio-Acoustic Fish Fence. It will be important to insure that the sound from the sound projector array 'couples' with the bubble curtain, which could be incorporated in the design of the deployment system, and could be field-tested before the system went into functional operation.

## Implementation and Operational Issues

As outlined in the *Feasibility Study to Limit the Invasion of Asian Carp in the Upper Mississippi River Basin* (FishPro 2004), evolution of the bio-engineering approach has resulted in several valuable lessons that can benefit future efforts to achieve maximum efficiency in acoustical barriers and deterrents. The first lesson is that there are no overnight successes. A second lesson is that fish response to sound varies among species, and environmental conditions, including factors such as morphology of the site, water current patterns, seasonal stratification and turbidity, among others, can influence performance of a system both from the standpoint of the physics of sound in water and the physiological response of fish to sound. The third lesson is that field scale testing and monitoring is absolutely necessary throughout all phases of development, such as acquisition of baseline information, typical behavior of the target species, and installation and testing of the full scale system. It has been observed that smaller, less mature fish generally appear to have lower sensitivity to sound than larger, more mature fish.

Differences in basic sensory capability such as this could be very important in determining the specifications of sound behavior modification and/or deterrent systems.

Some of the common causes of acoustic deterrent system failure include: 1) emission of sounds at frequencies outside the main hearing band of fish (0 to 600 kHz); 2) ineffective signal types; 3) inadequate sound levels; 4) failure to compensate for background noise; 5) unsuitable or inadequate sound generation equipment; 6) unusual sound propagation patterns caused by interference; 7) excessive water velocities; 8) failure to provide a clear escape route or diversion area; or 9) poor design.

# Appendix 6.6. Additional Considerations for the Enhancement of Commercial Harvest of Asian Carps

The extent of commercial harvest of Asian carps is controlled by commercial fishers and the market for the fish. To enhance the harvest of Asian carps, it may be necessary to work with harvesters, fishery product developers and testers, processors, marketers, and consumers. Other than the inherent risk involved in beginning new industries, the primary impediments to enhancement of commercial markets for Asian carps for human consumption include a perception that "carp" flesh is low quality and the presence of intramuscular bones (Perea 2002). However, research has been conducted on the marketability of fresh Asian carps (Crawford et al. 1978, Engle 1978) and in a side-by-side taste test, bighead carp was preferred over catfish (Shelton and Smitherman 1984). Chapman (2004) described methods to de-bone the filets and to prepare the bone-in filets in ways that render the bones less offensive. While intramuscular bones are an issue with the fresh product, canning offers a viable alternative. The marketability of canned silver carp was tested by Woodruff (1978) and several studies have examined consumer acceptance of canned bighead carp (Figure 6.6.1; Engle and Kouka 1995; Thomas and Engle 1995; Freeman 1999). Additional research on development and testing of products for human consumption, as well as and additional products not for human consumption is needed to create a demand for the large number of fishes that can be harvested from the Mississippi River Basin.

**Figure 6.6.1.** Canned bighead carp. Photo courtesy of Carole Engle, University of Arkansas at Pine Bluff.

It is clear that with a high degree of fishing effort Asian carps can be harvested to reduce their populations. In their native China, wild populations of Asian carps are often considered over-harvested (Yi et al. 1988). Although it is highly unlikely that Asian carps could be extirpated from the United States by fishing alone, and the amount of fishing pressure required to substantially reduce the population of Asian carps is unknown, decreasing the population of Asian carps to a substantial degree through harvest enhancement has a reasonable probability of success. Enhanced commercial harvest is also an approach that can be initiated immediately.

Enhancement of Asian carp harvest and markets would create jobs for commercial fishers and processors. Potentially, it would generate new support for ecosystem improvement from previously untapped constituencies. Market creation for a broadly distributed product could create substantial localized economic benefits. Product development that is under exploration in Illinois could lead to over 350 jobs, with potential expansion to other states if desirable (personal communication, Steve Shults, Illinois Department of Natural Resources). Product development should include food products for humans and animals. Product development initiatives should re-examine material published by the National Sea Grant College Program in the 1970s and 1980s that dealt with products and market development for under-utilized species and the by-catch from targeted capture fisheries.

Another barrier is the inconsistent supply of fish (personal communication, Duane Chapman, USGS). While Asian carps are abundant in the Mississippi River Basin, seasonal fluctuations in catch and weather conditions could cause an irregular supply. If Asian carp populations are successfully depleted through harvest, this will create a problem with fish for the processing facilities. It is possible that commercial harvest of alternate species, such as common carp, or Asian carps from aquaculture may supplement fish to facilitate a consistent supply for processors during times of short supply of feral Asian carps. If efforts to reduce, or eliminate, populations of Asian carps are successful, and ecosystems are restored to previous biological communities, the potential for supplying processors with native species should be explored.

Harvest enhancement has potential negative, as well as, positive effects. By-catch of non-target species can be problematic. A sustainable market for Asian carps demands that prices rise so a commercial fishing operation can make a reasonable profit. If a reliable, profitable market exists, intentional stocking of Asian carps into additional waters to increase sources of these fishes could result. Asian carps are known to live and grow well in a variety of lacustrine habitats (Li and Senlin 1995, Xie 2003) and can recruit successfully in reservoirs that have tributaries with sufficient length to support spawning (Nikolsky 1963, Tripathi 1989). The degree to which such illegal stocking is a threat to lakes and reservoirs in the United States is unknown, but must be considered. Intentional unauthorized stocking of fish has occurred elsewhere in the country. Yellowstone National Park where lake trout (*Salvelinus namaycush*) were illegally stocked is a notable example (National Parks Conservation Association 2004). Possession or transportation of *live* Asian carps by commercial or recreational anglers should be made illegal, but this will not completely eliminate the risk.

Commercial markets based on the sustained presence of nuisance species may conflict with an accepted ecological restoration paradigm for natural resources managers. It is generally acknowledged that "habitat restoration", or even "species restoration" does not require a complete return of an ecosystem to a pre-European settlement character to be considered beneficial or successful. Restoration can seek to achieve meaningful targets for ecosystem structure and function based on analysis of reference habitats and historic conditions (Restore America's Estuaries 2002). Management efforts that provide for improved sustainability and health of native aquatic communities and habitats will be an important component of an integrated pest management program to reduce adverse effects of Asian carps.

Population reduction through harvest enhancement is likely to be an important component of an integrated pest management program; however, harvest enhancement alone is not expected to eradicate feral populations. The abundance of feral populations may continue to increase if harvest is not sustained, and markets and commercial enterprises do not persist. Therefore, feral populations may need to be sustained to allow commercial harvest and marketing operations to persist until research is completed and additional components of an integrated pest management program can be developed and implemented.

A successful, large-scale market for Asian carps will create a constituency that depends on maintenance of feral populations. The capital required for development (e.g., surimi or other highly processed foods) and the generation of a moderate-sized labor force may result in a desire and political pressure for the continued availability of an abundant supply of Asian carps. If sustainable populations of Asian carps are required to support these businesses, this may present an obstacle to achieving meaningful restoration goals for the Mississippi ecosystem.

Despite these concerns, harvest enhancement is the only method likely to result in substantial lowering of Asian carp populations over the near term, and it is the opinion of this Working Group that harvest enhancement should be a primary goal in the control of Asian carps. These stated concerns may be ameliorated if 1) Mississippi Basin natural resources managers agree that restoration targets can be met in the presence of controlled (rather than eliminated) populations of Asian carps; 2) markets are developed with Asian carp eradication as a goal; or

3) financial protections or exit strategies for investors are established prior to any market development.

Bighead and silver carps are more net shy than most native fishes and are not susceptible to standardized research methods for sampling fish (Stancill 2003, Ickes et al. 2005). However, directed fishing within certain habitat types can be successful at trapping large numbers of adult bighead and silver carps. Bighead and silver carps are susceptible to being driven by boats into entanglement gear if they can be trapped in areas with limited egress (Li and Senlin 1995). Likewise, Asian carps are sometimes susceptible to hoop netting (Figure 6.6.2). Most of the commercially harvested black carp reported in the United States have been collected in hoop nets (Nico et al. 2005). However, capture of Asian carps may require that fishers develop, learn, and apply new techniques. Techniques to capture Asian carps might not be available in all environments occupied by the fish. In this case, development and evaluation of entirely new methods and gears should be completed. Commercial fishers are likely to be the most innovative fishers, but transfer of information from one to another is generally very low. There appear to be economic incentives for successful fishers to avoid such information transfer. Nevertheless, to maximize harvest, technology transfer should move both ways between private and government entities. Government agencies should ensure that harvest technology is transferred between sub-basins.

**Figure 6.6.2.** Commercial fishers harvesting bighead carp with a hoopnet in Louisiana. Photo courtesy of Jody David, Louisiana Department of Wildlife and Fisheries.

A bounty system could increase the harvest of Asian carps, but would require a very high degree of oversight and funding. Under a federally funded bounty system, such as that implemented for nutria (*Myocastor coypus*) control in Louisiana (Louisiana Department of Wildlife and Fisheries 2003), federal money would pay for harvested Asian carps. The carcasses could be channeled into commercial markets if they existed, or be provided to commercial industries free of charge or at a reduced rate as a subsidy to assist in the development of those markets. To be effective, bounties might have to be directed at fish from relevant "hotspots". Otherwise, fishes could be taken from aquaculture ponds or river sections that were less meaningful for control purposes and submitted for bounty payments. There could be enforcement difficulties in the implementation of bounties that restrict the capture locations of the fish because it will be impossible, without excessive expense, to determine the location of capture. Despite the potential benefits of a bounty system, the high cost and difficulties inherent in managing a bounty system seem prohibitive. We do not recommend instituting bounties or a study of the effectiveness of a bounty system.

A subsidy that may have promise is provision of transportation from the fisher to markets and processors. Refrigerated trucks or portable processing units could be provided at the boat ramp. These vehicles could be located in areas where managers wish to direct harvest. This form of subsidy has several positive aspects. Markets for Asian carps exist, but the costs of transportation can be prohibitive for small commercial fishers. The quality of fish delivered to market would be improved, due to better transportation and handling once the fish are landed. Providing transportation would mean that experienced fishers spend more time fishing and less time transporting, storing, or processing fish. The expense of such subsidy would be known before implementation, unlike a bounty that would depend on the numbers of fish harvested. Lastly, this form of subsidy would be simple to phase out, should it no longer be required to sustain a high rate of commercial fishing. Whether this form of subsidy would be economically feasible, accepted by fishers, practical to implement, or would provide sufficient economic incentive to substantially increase harvest is unknown. However the potential benefits of this harvest support system should be investigated. The administration and costs of fish transportation might be born by federal (perhaps Department of Interior or Small Business Administration) or state entities (perhaps State Departments of Commerce) or by the fish processors.

Another incentive could be contract fisheries. In this case, commercial fishers are paid a fee for fishing within designated high-priority areas. Payment could be based on the removal of a certain biomass or in selected situations to stimulate interest in fishing areas with low population densities. Another example is opening a contract fishery specifically for Asian carps in areas that are closed to other commercial fishing. This strategy has the advantage that populations of Asian carps could be reduced in areas where they do the most damage or where there is high potential that they will spread to new areas. While the fishers are free to sell their catch, the fishing pressure can remain high even when the price of the fish would not provide sufficient economic return. This may be important if populations of Asian carps are reduced greatly within an area of high importance for resource management. As with other types of harvest enhancement, administering and enforcing the program must be weighed against the value of fish removal in the specific area.

Development of Asian carp products for human consumption and investigation of market acceptability of those products should be encouraged. Some methods of processing Asian carps (e.g., canning or de-boning) eliminate the issue of boniness (Stone et al. 2000). Canned bighead carp compared favorably to tuna in taste tests (Stone et al. 2000). Minced bighead carp may be used in fish sticks or patties, fish cakes, fish paste, fish soups, fish surimi (crab substitute), fish jelly (kamaboko), or dehydrated fish powder (Stoller Fisheries 2005). The minced product resulting from de-boning fish can even be used as a highly nutritious substitute for ground meat products, especially in dishes with flavored seasonings or sauces. Other Asian carp species could possibly be processed in a similar fashion. Minced Asian carps could compete with low-cost fish derived from ocean fisheries, and would be made primarily from the white meat portion of the fish.

Development of products and markets for whole fish, and portions of fish that are not acceptable for human consumption, should be encouraged. One problem that must be overcome when marketing for human consumption is that bighead carp have a relatively low dressout weight, especially when only the white meat portions are used (Engle and Brown 1998). Bighead carps have large heads and, for white meat products, the strip of red meat along the lateral line must be removed (Stone et al. 2000), which increases the expense of processing and decreases dress-out weight. Even less information on dress-out weight is available for other Asian carps, but silver carp have very similar morphology to bighead carp and are likely to have similar dress-out weights. Thus, while products made from the white meat may be marketable and have a relatively high-value, it would also be beneficial to develop uses, such as pet foods, for the remainder of the fish, if such products will be economically feasible. In addition to the market for human consumption, there are many other outlets for fish flesh that could potentially create demand for large amounts of Asian carps. These include a protein source for livestock rations (Maddox et al. 1978), pet food, fish oils for the health food industry, fertilizer, and use as bait for crabs, crawfish, or other commercial fisheries.

Funding and low interest loans to provide the above encouragements should most likely come from sources like the Small Business Administration, and/or state commerce departments. While use of a wild product would be somewhat outside their normal area of operation, federal and state agricultural agencies have experience in encouraging the development of new products for agricultural commodities and these agencies should assist in these endeavors. Requests for proposals should be requested from private, university, and government entities.

# Appendix 6.7. Additional Considerations Regarding the Use of Biological Controls to Reduce the Abundance of Feral Asian Carps

The introduction of disease agents, parasites, or predators that attack a target species may provide methods for biological control of some organisms. For nuisance species, the control agent typically is imported from the native range of the target species (i.e., a "natural enemy"). It is critical that an imported biological control agent prey specifically on the target species and not on native non-target species. Substantial research, planning, and care are needed to avoid introducing additional pest species (Cox 2004).

Spring viraemia of carp has been proposed in Australia for common carp control (Crane and Eaton 1997), however the use of a disease agent as a biological control is not recommended in this plan. Spring viraemia of carp is caused by the virus *Rhabdovirus carpio* and can sometimes cause epizootics and mass mortality of several species of carps, especially common carp (Crane and Eaton 1997). However, spring viraemia of carp is a highly dangerous fish disease, reportable to the Office International des Epizootics (Office International des Epizootics 2003). When a case of spring viraemia of carp has been confirmed in the United States by a USDA approved laboratory, the state veterinarian and appropriate USDA, Animal and Plant Health Inspection Service, Veterinary Services officials must be notified (Hartmann et al. 2004). Spring viraemia of carp has also been isolated from several non-carp and even non-cyprinid species. Spring viraemia of carp is not known to have caused the eradication of common carp in any place where epizootics have occurred, and populations eventually develop some resistance to the virus (Crane and Eaton 1997). Spring viraemia of carp is not likely to result in long term control of Asian carps and may be pathogenic in native fishes, especially cyprinids, one of the most diverse groups of fishes in North America. Therefore, use of spring viraemia of carp as a biological control agent is not recommended. However, it should be noted that spring viraemia of carp is likely to spread within the Mississippi River Basin without intentional human intervention, and may cause localized mass mortalities of carps.

Predators have been reported to lead to the decline of some Asian carp populations (Kolar et al. 2005). Stocking predator fishes (e.g., northern pike, walleyes, and largemouth bass) has been used commonly by fisheries managers in the past to control early life stages of common carp. However, these fish control projects have highly variable effectiveness and rarely have included adequate monitoring to truly assess success (Meronek et al. 1996). Programs to stock predators as a means of reducing prey populations must consider the size and abundance of the predator, the size and abundance of the target prey, the size and abundance of alternative prey, and the physical-chemical characteristics of the habitat. Unfortunately, little is known about the susceptibility of Asian carps to native piscivores. Experience in aquaculture indicates that bighead and grass carps are highly susceptible to predacious fishes (personal communication, Mike Freeze, Keo Fish Farm), but little is known about which native predators will prey effectively on Asian carps, at what sizes, and the effects of environmental factors or habitat types on this relationship. Research is needed to determine which native predator fish can effectively prey on Asian carps, the vulnerability (sizes and life stages) of Asian carps to predation, and the stocking size and density of predators required for effective population control. Most rivers in the United States where Asian carps are abundant are highly turbid which may limit effectiveness of sight-feeding predators. It is not known if native predators will preferentially consume Asian carps or native prey fish. Stocking of native predators can have negative as well as positive effects, and should not be done indiscriminately. Adequate evaluation of the effects on both Asian carps and native fish populations should accompany efforts to control Asian carps through predator enhancement.

# Appendix 6.8. Additional Information on "Daughterless Carp" Technology

The concept of "daughterless carp" will provide an elegant and practical solution to reproduction of feral Asian carps, if it works. Daughterless carp technology is being developed in Australia for controlling the common carp, which is a severe pest there (Department of Conservation 2003). The Australian Federal Government and the Provincial Governments of New South Wales Queensland, Victoria, and South Australia are promoting this concept strongly, with substantial funding to conduct research and develop management strategies and techniques. The target of Australian efforts is the common carp; however, the basic concept should work on other species of fish, including Asian carps. It must be emphasized, however, that the Australian program, which began in 2002, is still in the development stage and has not even been tested under controlled field simulation conditions to determine the safety and effectiveness of the concept. For maximum efficiency, it seems wise to allow the work with common carp to progress and to work the "bugs" out of this technology before proceeding with another species. Research of daughterless carp technology to control Asian carps should begin only after the technology has been applied to common carp in the wild and has shown evidence of success.

Daughterless carp are produced by manipulating common carp genes so that all offspring produced by the experimental animals are phenotypically males. When these males mate with "normal" females, once again, all offspring are phenotypic males. In theory, as the numbers of males carrying the daughterless genes builds to a larger and larger proportion of the population, the number of normal females continues to fall. Fewer and fewer females are produced each generation until the common carp population is mostly males. The total reproductive potential of the population is reduced drastically and the number of common carp in the fish community falls to very low levels. The length of time needed to accomplish the desired reduction in common carp numbers will be determined by the size of the initial population, the number of daughterless males that can be introduced into it, and the capability of the daughterless males to survive and function normally within the breeding population. A period of 20 – 30 years has been estimated as necessary to reduce common carp populations in Australia to the desired levels (CISRO 2002), with large-scale production and stocking of daughterless common carp over most of those years. In theory, common carp populations can be forced into extinction, but it is not known whether or not this can be accomplished in practice.

The genetic basis of this technology is as follows: Every embryo has the potential to be a phenotypic male or a phenotypic female. The actions of specific promoters during embryonic development determine the gender that results. Aromatase is the key enzyme responsible for stimulating female development at the embryo stage in common carp and other species of fish. When this key enzyme is not activated, the embryo becomes a phenotypic male, regardless of its genotype. The "daughterless" gene inhibits production of this enzyme. The gene is heritable; when these males mature they will produce sperm carrying the "daughterless" gene, even if they are genetically female.

The daughterless genetic sequence is the sequence of genes that inhibits the activation of the aromatase enzyme, and is found naturally in all genotypically male common carp (and in many other fishes as well). To make a daughterless male common carp, this gene is replicated and inserted into multiple other gene locations, so that the offspring of the daughterless carp are phenotypically male regardless of whether they are genotypically male or female. Thus, although the techniques involved in the processes of inserting the daughterless gene into common carp chromosomes are considered to be genetic engineering, no interspecies transgenic manipulations are required. The daughterless genetic sequence is found naturally in the common carp, is species-specific, and, therefore, is expressed only in fish of the species from which the material was derived. Risk assessment research would be needed to determine if the transgene could be spread to closely related species and what the potential impacts of this might be.

The release of genetically modified daughterless common carp into feral populations is predicted to lead eventually to all male populations and, as a result, extirpation of that population. This result is, however, dependent upon the daughterless common carp having equivalent mating success, survival through early life stages, and survival to maturity in comparison to their normal counterparts in the feral population. If the daughterless gene does not result in negative natural selection initially or in subsequent generations, the gene should spread rapidly through the feral population. Models of these dynamics predict extirpation of the target population if sufficient stocking of daughterless common carp is continued over enough years. Such models include a series of assumptions that are yet to be verified. Even if a slightly lower degree of fitness for the daughterless common carp is assumed, sex ratios skewed toward males should result and common carp numbers would be expected to be reduced. This technology has potential application not only with Asian carps, but with a variety of other nonnative fishes.

One disadvantage of this technique is that it requires, at its onset, release of additional individuals of the species targeted for eradication into the environment. The numbers of individuals added would be relatively small in comparison to the size of the total target population and the numbers of young fish would start to decline as soon as the fish carrying the daughterless gene attempted to spawn. The ecosystem impacts of stocking daughterless fish could be minimal in comparison to the long range benefits for bighead, grass, and silver carps; however this would need to be further researched. This technique is likely not applicable to black carp because, due to their food preferences, introduced individuals could pose a serious threat to many of the remaining populations of threatened and endangered mollusks (Nico et al. 2005).

The development of daughterless common carp technology should be monitored and if successful in common carp control, this technology should be expanded to Asian carps. Research to develop daughterless common carp has been under way since 2002. Common carp achieve reproductive status at an earlier age than Asian carps and thus are a better and faster test of the technology than Asian carps. At this stage of development, expanding the technology to Asian carps would constitute duplication of effort. It would be imprudent to invest in the production of daughterless Asian carps until successes with daughterless common carp are seen.

Adequately addressing policy, regulatory, and legal considerations related to developing a transgenic Asian carp could take many years. Kapuscinski and Patronski (2005) reviewed the relevant policy and regulatory considerations related to development and release of a transgenic animal for biological control in the United States. It should also be noted that this technology is patented by the Australian government, and research in this area should progress only with a full understanding of the legal implications, and may require working with the Commonwealth Scientific and Industrial Research Organization.

For additional information on this topic see CISRO (2002) and Thresher et al. (2002).

# Appendix 6.9. Additional Considerations Regarding the Development and Application of Habitat and Hydrological Manipulations to Control Feral Asian Carps

The recommended alternative in the USACE (2004) Final Feasibility Report for the Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Feasibility Study includes 12 categories of restoration measures potentially benefiting 388,281 acres of aquatic and terrestrial habitat. Identified restoration measures include: island building, fish passage, floodplain restoration, water level management of navigation pools, backwater restoration and water management, side channel restoration, wing dike alteration, island protection, increasing topographic diversity, and implementing dam-point control. In addition, the USACE's Report includes $205 million in mitigation measures to offset the adverse effects of the proposed navigation improvements on the Upper Mississippi River Basin system. Approximately $60 million of this mitigation cost is targeted to fishery effects.

It is well within the scope of these restoration and mitigation projects to consider actions to prevent the spread, limit the abundance, and minimize the effects of Asian carps on aquatic habitats and native fish communities. Restoration planning should occur systemically and attempt to identify a mosaic of projects that provide the least possible benefit to Asian carps, yet achieves pre-determined goals for habitat improvements and native aquatic community sustainability. For example, Nico et al. (2005) discussed a number of environmental and habitat requirements that are necessary to stimulate black carp to spawn, as well as for the survival of eggs and larvae following a spawning event. Habitat restoration planners must understand the biological needs of both native and nonnative species and develop plans that will provide the greatest benefits possible to native species.

Habitat manipulations that might be useful in controlling Asian carps include changes in floodplain connectivity or the timing of that connectivity, barriers to upstream spawning migrations, changes in the timing of releases from reservoirs, or changes in wing dike morphology. Asian carps that have been introduced to the United States are rheophilic spawners with semi-buoyant eggs that are thought to require a long stretch of flowing water for development and recruitment (Soin and Sukhanova 1972; Yi et al. 1988). Juveniles of these fish seek out slow moving off-channel habitats (Kolar et al. 2005). Habitat manipulations that shortcut these life-cycle characteristics have great potential to control Asian carp populations. Blocking upstream migration through the use of low-head dams or other structures would be an example of this strategy. Blocking of upstream migration would be especially useful if Asian carps are established within a reservoir, because the only available spawning habitat would be inaccessible to them. Similarly, barriers and low head dams could be used to create low-velocity sections of river that would allow the eggs to settle to the bottom and die. However, such barriers may also prevent upstream spawning migrations or recruitment of native species and must be considered cautiously and with a holistic view of the entire biological community.

It may be possible to design habitats that are very attractive to Asian carps and that simultaneously allow their easy removal or to alter habitats that are currently very attractive to Asian carps to enhance the ability to remove the fish. For example, habitats attractive to juvenile Asian carps might be modified so that they can be fished or drained. The spawning habits of Asian carps in the United States are not understood fully, but in China large numbers of these species spawn in relatively few locations (Yi et al. 1988). It may be possible to identify locations where large numbers of carp spawn in the United States and focus fishing in these areas. It may also be possible to create habitats that encourage spawning in areas where the fish may be caught easily, or in which the eggs and larvae are not likely to survive. Adult bighead and silver carps are known to congregate in the low water velocity habitats behind certain types of wing dikes (unpublished data, Duane Chapman, USGS). Some of these wing dikes are easily fishable using standard gears and others are not. Minor modifications to wing dike structure might make fishing much more effective, by minimizing escape routes.

Habitat manipulations may be made that simply benefit native fishes over Asian carps. For example, the notching of wing dikes that has been done by the USACE for fish habitat improvement may affect Asian carps adversely. Although flow through notches carves scours that provide deeper water preferred by adult bighead and silver carps in the Missouri River, notching also allows exchange of river water into wing dike pools and increases water velocity within the wing dike pool, changes that may not be beneficial to Asian carps (unpublished data, Duane Chapman and Robb Jacobson, USGS). Data on wing dike usage by bighead and silver carps is being analyzed currently, and may shed light on this issue. The USACE's recent effort to create large amounts of shallow water habitat on the Missouri River should also be evaluated in terms of its effect on Asian carps. This effort may inadvertently create hundreds or thousands of acres of Asian carp nursery habitat. It is critical that habitat usage of Asian carps be understood and that habitat manipulations intended to benefit native fish be considered alongside their effects on Asian carps.

The timing of water releases through dams might be used in Asian carp control. Water rises are thought to initiate spawning of Asian carps (Yi et al. 1988). There may be ways to use timing of the release of water from dams to interfere with Asian carp spawning or increase their catchability. One simple way in which this might be achieved involves the propensity of Asian carps to congregate below dams, apparently for spawning or feeding (MICRA 1999; personal communication, Duane Chapman, USGS). A short-term slowing of the flow may allow the setting of nets and the removal of large numbers of fish. Other methods to control Asian carps using flow manipulations might involve floodplain connectivity or timing of spawning. Such methods would require further research before they are usable.

# Appendix 6.10. Additional Considerations Regarding the Use of Piscicides to Control Feral Asian Carps

Only two general piscicides and two selective piscicides [3-trifluoromethyl-4-nitrophenol (TFM) and Bayluscide®] are currently registered for use in the United States by the USEPA. Both selective piscicides are registered only for use to control sea lamprey in the Great Lakes and Lake Champlain.

Selective control of fishes requires that the target fish be more sensitive to the piscicides than non-target fishes. Rotenone and antimycin are general piscicides and are primarily used to kill all fish in the area of application. There have been rare instances in which these chemicals have been used selectively. Willis and Ling (2000), describe a technique for using rotenone to control nonnative mosquitofish (*Gambusia affinis*) in wetlands containing native black mudfish (*Neochanna diversus*), a species twice as resistant to rotenone as mosquitofish. Burress and Luhning (1969) and Cumming (1975) used antimycin to remove scaled fish from production ponds without affecting channel catfish. Radonski (1967) used antimycin to eliminate yellow perch (*Perca flavescens*) from a Wisconsin lake while leaving the remaining fish unharmed.

Because bighead, grass, and silver carps are more sensitive to rotenone and antimycin than channel catfish in production ponds, these chemicals are potentially useful in aquaculture. However, a limited number of studies (Henderson 1976, Marking and Bills 1981, Chapman et al. 2003) have shown that bighead, grass, and silver carps are not especially susceptible to rotenone compared with published toxicity values of most other fish (Marking and Bills 1976, Berger et al. 1969). The contact time required to kill bighead, grass, and silver carps using rotenone and antimycin requires further investigation. Because treating waters with these chemicals to control wild Asian carps would require using concentrations that would also kill many native species, rotenone and antimycin should be considered for removing Asian carps only when sensitive native species are not present or are of insignificant concern. Other obstacles to implementing chemical control of Asian carps in the wild is that no field testing in open waters has been conducted to specifically target bighead, grass, or silver carps; the sensitivity of black carp to antimycin and rotenone is unknown; chemical treatments are expensive and treatment of the Mississippi River and other large rivers in the United States is not logistically or economically feasible; chemical treatments would need to be conducted regularly; treatments may adversely effect the Endangered pallid sturgeon (*Scaphirhyncus albus*); and treatments would require public and regulatory agency support.

However, there are situations in which using rotenone or antimycin to control Asian carp populations may be warranted, especially when Asian carps are congregated in areas from which escape is impossible or unlikely such as isolated backwater areas. Larval and early juvenile Asian carps are sometimes present in large numbers in intermittently connected backwaters after flood waters recede (unpublished data, Nate Caswell, USFWS; personal communication, Duane Chapman, USGS). Fish in these waters must remain there until flooding reconnects the backwater with the river. While the relative importance of these habitats to Asian carps is not understood and other habitats are also used by juvenile Asian carps (Kolar et al. 2005; unpublished data, Louise Mauldin, USFWS), their presence in these isolated habitats may provide an opportunity to destroy large numbers of juvenile Asian carps before they can return to the river. Before treatment, backwaters would need to be assessed for the presence of imperiled fishes and the relative abundance of Asian carps. Criteria would need to be developed to decide which backwaters are suitable for treatment. Economic feasibility and the overall efficacy of such treatments in reducing Asian carp populations would also need to be evaluated. Other situations in which targeted chemical treatments could be used to control populations of Asian carps may occur when the fishes are congregated for spawning or over-wintering. Strategic piscicide use could also be useful in reducing the spread of Asian carps by increasing the effectiveness of barriers in large river systems.

Piscicide-laced baits represent a special application of piscicides. Poisoned baits have been used to control grass carp (Rowe 1999; Thomas 2004) and common carp (Rach et al. 1994). Such applications require training the target fish on unpoisoned bait followed by application of the poisoned bait. Although complete removal of grass carp with poisoned bait has not always been possible, and mortality of non-target fishes sometimes occurs (Gehrke 2003, Rowe 2003), use of rotenone-laced bait such as Prentox® for grass carp may be useful if specific areas where grass carp are problematic can be identified. The extremely strong crushing teeth of black carp allow them to crush food items that cannot be crushed by any native North American fish of similar size. It seems possible that baits for black carp could be devised that would be little consumed by native fishes. Ideally, such bait should be of a size and character that would not easily break down to smaller pieces which then could be consumed by non-target organisms. Development of baits at this time may be premature because the density of black carp in the wild is low and the locations to be baited are not understood. Baits should be developed if densities of feral black carp increase. Baits could be targeted in areas where black carp could potentially feed on threatened and endangered mollusks.

# Appendix 6.11. Additional Education and Outreach Recommendations

**Table 6.11.** Education and outreach recommendations identified in sections other than Goal 3.5 are referenced by Goal, Recommendation, and page number.

| Goal | Recommendation | | Page |
|---|---|---|---|
| 3.1 | 3.1.1.1 | Assist states develop, promulgate, and enforce regulations that manage the harvest, transport, import, trade, and release of live wild-harvested aquatic bait. | 31 |
| | 3.1.1.2 | Develop and provide information to commercial and recreational baitfish harvesters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | 32 |
| | 3.1.2.1 | Encourage states to develop regulations that prohibit the stocking of any diploid Asian carps into non-aquaculture waters for biological control. | 33 |
| | 3.1.3.1 | Encourage states that allow the legal importation of grass carp to adopt consistent, uniform regulations that allow only certified triploid grass carp to be shipped or stocked. | 34 |
| | 3.1.3.2 | Encourage states to conduct routine and random inspections of all live grass carp shipments within the state. | 34 |
| | 3.1.5.2 | Encourage states to allow stocking triploid grass carp for biological control in non-aquaculture waters only within watersheds where grass carp are already present in the wild. | 36 |
| | 3.1.6.2 | Develop and provide information on the USFWS Triploid Grass Carp Inspection and Certification Program. | 38 |
| | 3.1.7.1 | Investigate fully the risks associated with ballast water transfers or other means of water transfer by barges and ships, and live well transfers by boats. | 39 |
| | 3.1.7.2 | Inform boaters, barge operators, and others of the risks of moving infested water and encourage voluntary actions to reduce this risk. | 39 |
| | 3.1.8.1 | Natural resources managers should employ pathway management tools, such as Hazard Analysis and Critical Control Point planning in the review of Standard Operating Procedures, to prevent introductions of Asian carps through natural resources management related pathways. | 39 |
| | 3.1.8.2 | Develop and provide information to natural resources managers and field staff that will help prevent unintentional introductions and spread of feral Asian carps. | 40 |
| | 3.1.9.2 | Inform USFWS Law Enforcement Officers, other federal inspectors, and state conservation law enforcement officers about laws that apply to the import of live Asian carps, the importance of preventing the illegal import of Asian carps, and Asian carp identification. | 41 |
| | 3.1.9.3 | Inform potential importers of applicable state and federal laws and associated risks with international shipments of live Asian carps. | 41 |
| | 3.1.12.1 | Urge the development and enforcement of state regulations that prohibit the production of Asian carps at poorly sited facilities. | 44 |

**Table 6.11.** Continued.

| Goal | Recommendation | | Page |
|---|---|---|---|
| | 3.1.12.2 | Develop and provide information to Asian carp producers and growers that will help upgrade poorly sited facilities such that they are no longer high-risk to contain farm-raised carps and prevent accidental introductions. | 44 |
| | 3.1.13.2 | Develop an information module on economic and effective alternatives to replace the use of bighead and black carps on aquaculture facilities. | 45 |
| | 3.1.14.2 | Encourage states to develop regulations that allow for random inspections of live fish shipments into and within the state. | 46 |
| | 3.1.14.3 | Prohibit the use of surface waters containing Asian carps from being used in aquaculture facilities unless effective treatment is in place with a monitoring program. | 46 |
| | 3.1.15.4 | States should encourage the use of only certified triploid grass carp on aquaculture facilities within watersheds where grass carp are self-sustaining in the wild. | 48 |
| | 3.1.15.7 | Encourage states to restrict the use of bighead carp on aquaculture facilities within watersheds with self-sustaining populations to certified triploids only. | 49 |
| | 3.1.16.1 | Where legal for commercial or recreational fishers to possess Asian carps, encourage states to prohibit the possession of live wild-caught Asian carps. | 56 |
| | 3.1.16.3 | Develop an information module and provide materials to commercial and recreational fishers and commercial live haulers that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | 56 |
| | 3.1.17.5 | Develop an information module and provide materials to commercial transporters of live farm-raised Asian carps that will help prevent accidental and deliberate unauthorized introductions. | 58 |
| | 3.1.19.1 | Urge states to prohibit the sale, live transport, and unauthorized release of live Asian carps for non-commercial uses. | 61 |
| | 3.1.19.2 | Urge states, that allow sales of live Asian carps for human consumption to require retail grocers to kill the fish using prescribed humane methods, immediately upon sale. | 62 |
| | 3.1.19.3 | Use educational campaigns such as Habitattitude$_{TM}$ to convey messages to the public that they should not release live Asian carps. | 62 |
| | 3.1.19.4 | Develop an information module and provide materials to producers, growers, marketers, and foodfish consumers of live Asian carps that will help prevent accidental and deliberate unauthorized introductions. | 62 |
| | 3.1.20.1 | Encourage states to prohibit the trade of Asian carps for aquaria and hobby purposes. | 63 |
| | 3.1.21.1 | Urge states to develop and enforce regulations to reduce risks associated with the possession and disposal of Asian carps for research and exhibition purposes. | 64 |

**Table 6.11.** Continued.

| Goal | Recommendation | | Page |
|---|---|---|---|
| | 3.1.21.2 | Develop an information module and provide materials to the academic and research communities that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | 64 |
| | 3.1.22.1 | Develop an information module and provide materials to recreational fishers and boaters that will help prevent accidental and deliberate unauthorized introductions of Asian carps. | 65 |
| 3.2 | 3.2.2.1 | Develop and implement redundant barrier systems within the Chicago Sanitary and Ship Canal to limit the unrestricted access of Asian carps to Lake Michigan. | 68 |
| | 3.2.2.4 | Identify additional containment measures needed to limit intrabasin movements of feral populations of Asian carps within the Mississippi River and other basins where established. | 71 |
| | 3.2.5.1 | Develop a database and communication network with agencies that regulate Asian carp possession. | 75 |
| | 3.2.5.2 | Create an information sharing system with early detection monitoring and rapid response project managers. | 75 |
| | 3.2.6.1 | Develop a website and centralized databases to provide information on early detection and rapid response programs. | 76 |
| | 3.2.6.2 | Develop a list-server to provide a forum for information exchange. | 76 |
| | 3.2.6.3 | Utilize and support the Nonindigenous Aquatic Species Information Center for accurate and spatially referenced biogeographic information and the Nonindigenous Aquatic Species Alert System to track expansion. | 76 |
| 3.3 | 3.3.3.2 | Inform recreational fishers about Asian carp harvest and preparation methods. | 82 |
| 3.4 | 3.4.2.1 | Educate boaters to avoid damage from jumping silver carp. | 90 |
| 3.7 | 3.7.1.4 | Seek “new” funds from various sources to implement this plan. | 111 |
| | 3.7.1.7 | Develop an effective strategy for communication and coordination among those implementing recommendations for management and control of Asian carps. | 113 |

# Appendix 6.12. Additional Research Recommendations

**Table 6.12.** Research recommendations identified in sections other than Goal 3.6 are referenced by Goal, Recommendation, and page number.

| Goal | Recommendation | | Page |
|---|---|---|---|
| 3.1 | 3.1.7.1 | Investigate fully the risks associated with ballast water transfers or other means of water transfer by barges and ships, and live well transfers by boats. | 39 |
| | 3.1.13.1 | Form a coordinating research group that includes representatives from the aquaculture industry, the ethnic retail grocer industry, market scientists and developers, and aquaculture scientists to focus research efforts on the highest priority alternatives to the use of Asian carps. | 45 |
| | 3.1.15.5 | Verify functional sterility of triploid bighead carp and develop a triploid certification program for bighead carp**.** | 48 |
| 3.2 | 3.2.1.1 | Develop a Decision Support System to assist natural resources managers in prioritizing specific locations for the construction, maintenance, monitoring, or removal of barriers to carp dispersal. | 66 |
| | 3.2.1.2 | Evaluate the effectiveness afforded by alternative technical containment measures (i.e., physical and behavioral barriers). | 67 |
| | 3.2.1.3 | Promote, support, and provide technical analysis and comment for the field testing of novel containment methods. | 67 |
| | 3.2.1.4 | Anticipate and address consequences of specific containment actions on native biological communities**.** | 68 |
| | 3.2.2.1 | Develop and implement redundant barrier systems within the Chicago Sanitary and Ship Canal to limit the unrestricted access of Asian carps to Lake Michigan. | 68 |
| | 3.2.2.3 | Construct and operate a Sound Projector Array-based acoustic bubble curtain fish deterrent at two locks and dams on the Upper Mississippi River to prevent the spread of Asian carps throughout the basin. | 70 |
| | 3.2.2.4 | Identify additional containment measures needed to limit intrabasin movements of feral populations of Asian carps within the Mississippi River and other basins where established**.** | 71 |
| | 3.2.3.1 | The USFWS and other natural resources management agencies should provide technical assistance and biological information to the USACE and participate in collaborative planning of fish passage structures. | 71 |
| | 3.2.4.1 | Develop an early detection Decision Support System to: 1) identify high risk locations susceptible to introductions or range expansions of Asian carps, 2) identify watersheds of special concern, 3) prioritize specific locations for implementing comprehensive early detection monitoring programs. | 73 |

**Table 6.12.** Continued.

| Goal | Recommendation | | Page |
|---|---|---|---|
| | 3.2.4.3 | Develop and conduct routine early detection monitoring programs in locations where risk of introductions or range expansions of Asian carps exists. | 74 |
| | 3.2.4.4 | Develop Rapid Response Plans that identify where rapid response actions can effectively eradicate Asian carps and how those actions will be carried out. | 74 |
| 3.3 | 3.3.1.1 | Determine life history parameters of Asian carps in the Mississippi River Basin. | 77 |
| | 3.3.1.2 | Create population, biomass, and recruitment models for Asian carps. | 78 |
| | 3.3.2.1 | Evaluate gear and harvest method effectiveness, develop new gears if necessary, and provide information to commercial fishers. | 78 |
| | 3.3.2.5 | Develop new markets for Asian carps. | 79 |
| | 3.3.2.6 | Determine contaminant concentrations in edible portions of feral Asian carps. | 80 |
| | 3.3.4.1 | Develop information on the factors that determine the efficacy of native predator enhancement to control Asian carps. | 83 |
| | 3.3.5.1 | Examine the potential efficacy of introduction of monosex tetraploid fish as a control method. | 84 |
| | 3.3.6.1 | Adapt “daughterless carp” genetic technology to Asian carps. | 85 |
| | 3.3.7.1 | Sex pheromone research should continue with the goal of production and application of field-applicable technologies. | 86 |
| | 3.3.7.2 | Investigate aggregation pheromones for juvenile Asian carps. | 86 |
| | 3.3.8.1 | Provide technical assistance and biological information to the USACE and participate in collaborative planning of habitat improvement projects (e.g., Navigation and Ecosystem Sustainability Program, Missouri River Mitigation Project, and other authorities). | 86 |
| | 3.3.9.1 | Determine effectiveness of registered piscicides to control Asian carps. | 87 |
| | 3.3.9.2 | Identify conditions where rotenone or antimycin could be used to control populations of Asian carps. | 87 |
| | 3.3.9.3 | Determine potential of other chemicals to control Asian carps. | 87 |
| | 3.3.9.4 | Determine feasibility and applicability of piscicide bait deployment to control black and grass carps. | 88 |
| 3.4 | 3.4.1.3 | Protect or restore native species through methods other than stocking. | 90 |
| 3.7 | 3.7.1.5 | Develop criteria and/or performance measures to evaluate the effectiveness of management and control efforts. | 112 |