



Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Dividing the waters: The case for hydrologic separation of the North American Great Lakes and Mississippi River Basins

Jerry L. Rasmussen ^{a,1}, Henry A. Regier ^{b,2}, Richard E. Sparks ^{c,*}, William W. Taylor ^{d,3}

^a Natural Resource Management Associates, 4 Cobblestone Lane, Le Claire, IA 52753, USA

^b Centre for Environment, University of Toronto, 33 Willcocks St., Suite 1016V, Toronto, ON, Canada M5S 3E8

^c National Great Rivers Research and Education Center, 5800 Godfrey Road HK129 Godfrey, IL 62035-2466, USA

^d Department of Fisheries and Wildlife, Michigan State University, 13 Natural Resources, East Lansing, MI 48824-1222, USA

ARTICLE INFO

Article history:

Received 28 April 2011

Accepted 23 May 2011

Available online xxxx

Communicated by: Marlene Evans

Keywords:

Invasive species

North American Great Lakes

Mississippi River Basin

Biodiversity threats

Risk assessment

Legislation

ABSTRACT

Legislation has been introduced this year in the U.S. Congress, but not yet enacted, that would direct the U.S. Army Corps of Engineers to complete a study of the options that would prevent the spread of aquatic nuisance species between the Great Lakes and Mississippi River Basins. Hydrologic separation is the only option which closes the aquatic connection between the two basins and does not require continuous operation and maintenance of various technologies that have some risk of failure. The one-time, capital cost to separate the two basins is widely acknowledged to be high, and the outstanding question is whether the costs are justified given the significant risk of future ecological damages and long-term economic losses. Interests opposing separation have mounted a public campaign that the news media have picked up to deny that hydrologic separation should be considered or that a problem even exists. The campaign rests on four assertions: (1) existing electric barriers in the Chicago canals are effective; (2) it is too late—the carps are already in the Great Lakes or soon will be; (3) Asian carps will not thrive in the Great Lakes due to inadequate food and spawning habitat; and (4) Asian carps are unlikely to cause serious harm. Our review of these assertions and the ecological and socio-economic threats to both basins supports our recommendation that the pending legislation be passed and that it include analysis of hydrologic separation of the two basins.

© 2011 International Association for Great Lakes Research. Published by Elsevier B.V. All rights reserved.

Introduction

Responding to a public health risk more than 100 years ago, engineers reversed the Chicago River and built the Chicago Sanitary and Ship Canal to carry sewage away from Lake Michigan, the city's source of drinking water (Hill, 2000). The canal breached the low natural divide between two of North America's iconic watersheds, the Great Lakes and the Mississippi River, thereby opening a shipping route for recreational boats and commercial barges, but also providing an invasion route for harmful aquatic species; two of which are currently of major concern, bighead (*Hypophthalmichthys nobilis*) and silver (*H. molitrix*) carp. The imminent threat of these invasive Asian carp swimming through the canal system and colonizing the Great Lakes has elicited legislation from the U. S. Congress (Water Resources Development Act, 2007) authorizing the U.S. Army Corps of Engineers (USACE) to conduct "a feasibility study of the range of options and technologies

available to prevent the spread of aquatic nuisance species between the Great Lakes and Mississippi River Basins through the Chicago Sanitary and Ship Canal and other aquatic pathways." However, more than three years passed before the USACE issued the study's first Draft Project Management Plan, and the completion date for the study has slipped to 2015 (USACE, 2010c). Additional legislation which has been introduced, but not yet enacted (U.S. House, 2011; U.S. Senate, 2011), would direct the USACE to complete its separation study within 18 months. Political support for this legislation threatens to be undermined by a media campaign based on the following four assertions:

1. Existing electric barriers (constructed in the Chicago Sanitary and Ship Canal to prevent migration of harmful aquatic species) have proven effective in blocking Asian carp; Asian carp recently captured on the Lake Michigan side of the barrier arrived by other means (Frede, 2010).
2. Asian carp have already found their way into the Great Lakes, or soon will, through various means such as the dumping of bait buckets by anglers or intentional transfers — therefore it is too late to prevent the invasion (Frede, 2010; McCloud, 2010; Stanek, 2010).
3. Asian carp will not thrive in the Great Lakes due to a lack of adequate food and spawning habitat (Fletcher, 2010; Golowinski, 2010).
4. Asian carp are not likely to cause serious damage to the Great Lakes ecosystem (Smith and Vandermeer, 2010).

* Corresponding author: Tel.: +1 618 786 2811.

E-mail addresses: ijrivers@aol.com (J.L. Rasmussen), hregier@rogers.com (H.A. Regier), rsparks@illinois.edu (R.E. Sparks), taylor@msu.edu (W.W. Taylor).

¹ Tel.: +1 563 940 7707.

² Present address: 10 Ernst Street, Elmira, ON, Canada, N3B 1K5. Tel.: +1 510 669 5552.

³ Tel.: +1 517 353 3048.

Our critical review of these assertions and the ecological and socio-economic threats to both basins supports our recommendations that the pending legislation needs to be passed and that it should include serious consideration of re-separation of the basins.

Are existing barriers effective?

The existing electric barriers in the Chicago Sanitary and Ship Canal are designed to repel, not kill fish. The voltages required to kill fish would also be dangerous to humans who might fall into the water. Electric barriers are subject to shut down due to power interruptions, accumulation of debris, and periodic maintenance (USACE, 2010b). The electric field near steel-hulled barges can be reduced, possibly inducing fish to remain close to the hulls to avoid shock as they transit the electric field (Dettmers et al., 2005). During flood events, temporary water connections can allow fish to bypass the existing electrical barriers (USACE, 2010a,b). On the upstream (lakeward) side of the electrical barriers, only narrow strips of land separate the Sanitary and Ship Canal from the Des Plaines River and the old Illinois and Michigan Canal, which are connected to the Illinois River, a tributary of the Mississippi River. In September 2008, floodwaters connected the Sanitary and Ship Canal with the Des Plaines River (USACE, 2010a). To reduce the risk of fish by-passing the electric barriers, the Corps of Engineers recommended construction of 34,600 ft (10,546 m) of concrete barricades and 33,400 ft (10,180 m) of Chain Link Fence with ¼-inch (6.35 mm) openings to separate the Des Plaines River floodplain from the Sanitary and Ship Canal at an estimated cost of \$13,174,000. To date, a portion of the barricade and fence system has been completed in the area most likely to flood and two culverts that connect the old, unused Illinois and Michigan Canal to the Sanitary and Ship Canal have been blocked (USACE, 2010a). The frequency and size of flood events that may provide direct access for adults, eggs, or larvae of Asian carp to Lake Michigan around the electrical barrier are still under analysis (USACE, 2010a). Most experts agree that permanent solutions to block Asian carp and other harmful aquatic species from invading the Great Lakes must look beyond electrical barrier systems.

In addition to by-passes and other potential failures to prevent upstream movements, one of the greatest deficiencies of electrical barriers or other permeable devices that allow the free flow of water and boats are their inability to block *downstream* movements. Electric fields cannot prevent downstream migration and drifting of invertebrates, fish eggs and larvae, and potentially harmful plants, parasites and disease organisms. Pulsed DC electric fields generally are not strong enough to kill drifting organisms and propagules (Jerde et al., 2010a). Risks of harmful species transfers downstream from the lakes to the Mississippi River Basin must be taken as seriously as the threats to the Great Lakes. Recent assessments indicate that there are more than 156 nonnative aquatic species restricted to either the Great Lakes or Mississippi River Basin (Jerde et al., 2010a). Of these, 10 species present in the Great Lakes could damage the Mississippi River Basin and 17 species present in the Mississippi River Basin could damage the Great Lakes (Jerde et al., 2010a).

Are Asian carps already in the Great Lakes?

Traditional electrofishing and netting methods have been used in attempts to detect the presence of Asian carp beyond the electric barriers. Far more sensitive methods are needed for accurate monitoring, especially near the leading edge of the invasion front, where the population will be initially low (Jerde et al., 2010a).

One such method, detection of bighead and silver carp DNA in water samples (environmental DNA, eDNA), was employed in parallel with conventional techniques, but the efforts were not integrated into a scientifically-based framework designed to validate this new methodology (Jerde et al., 2010b; Jerde et al., 2011). Due to its

novelty in this application, the eDNA methodology has been viewed by some as an unproven, experimental method of detecting the presence of Asian carp. However, the eDNA methodology has been used, documented, and accepted in other applications in aquatic environments (Ficetola et al., 2008).

An EPA audit report concluded: “When eDNA results are positive, the public can have a high degree of confidence that Asian carp DNA is present” (Blume et al., 2010). The eDNA results do not indicate how many fish were present, only that at least one live carp was in the vicinity or upstream of the sample location within a few days of the time the sample was taken (Jerde et al., 2010b). While it is possible that eDNA could be present in the absence of a live fish, it is highly unlikely that the overall temporal and spatial patterns of Asian carp eDNA detected over two years above the electrical barrier can be attributed to any source other than live Asian carp. Jerde et al. (2010b) report 32 positive detections of eDNA from bighead carp and 26 detections of silver carp eDNA upstream of the electric barriers, including one silver carp eDNA detection in Calumet Harbor on Lake Michigan. Silver carp eDNA was also detected in the Chicago River in downtown Chicago and in the river's North Shore Channel, both less than 1 km from Lake Michigan (Fig. 1).

To date, there is no evidence of reproducing populations of Asian carps in the canals upstream of the electric barriers or in Lake Michigan. To reproduce, males and females must mature, produce eggs and sperm, and find each other in sufficient numbers that many eggs are fertilized. Then the eggs, larvae and young fish must survive and grow to maturity. There are many obstacles to successful reproduction and recruitment that often cause invasions to fail many times before they succeed (Drake and Lodge, 2006). However, given enough time, even low probability events will ultimately occur.

Intentional releases also pose risks that need to be addressed, primarily through education and regulations that are carefully targeted and strictly enforced. To minimize the risks of overland transfers, public education programs have been undertaken and legal prohibitions on the sale, transport and possession of live Asian carp have been enacted at the city, state and federal levels (Finster, 2007).

In summary, it is likely that only very small numbers of Asian carps have accessed the Chicago waterways upstream of the electric barriers, but to date probably have not successfully reproduced.

Will Asian carps thrive in the Great Lakes?

Food sources and potential spawning areas in the Great Lakes and tributary rivers are available to support bighead and silver carp, despite assertions to the contrary that were based on misrepresentation of one bioenergetics paper (Cooke and Hill, 2010) and inadequate knowledge of the physical complexity of the Great Lakes. That paper carefully acknowledged the existence of other food sources omitted from the bioenergetics model due to lack of data on the various forms of organic carbon floating on the surface, suspended in the water column, or resting on the bottom. The paper also acknowledged the existence of locally favorable plankton conditions in productive embayments around the Great Lakes (e.g., Green Bay, Saginaw Bay, Lake St. Clair, Western Basin Lake Erie, etc.) and major tributary rivers. Silver carp have recently been reported to consume *Cladophora*, a genus of filamentous alga comprising several species that are found in abundance around the margins of the Great Lakes (personal communication, Leon Carl, USGS Midwest Area Regional Executive, to the 28 April 2011 meeting of the Asian Carp Regional Coordinating Council). Food availability was one of many factors considered in a Canadian government risk assessment that concluded it is reasonably certain that bighead and silver carp will reproduce and spread in the Great Lakes if they are provided access (Mandrak and Cudmore, 2004).

The Great Lakes and tributary rivers are neither too cold nor too stagnant to support Asian carp spawning. In Asia, bighead carp thrive

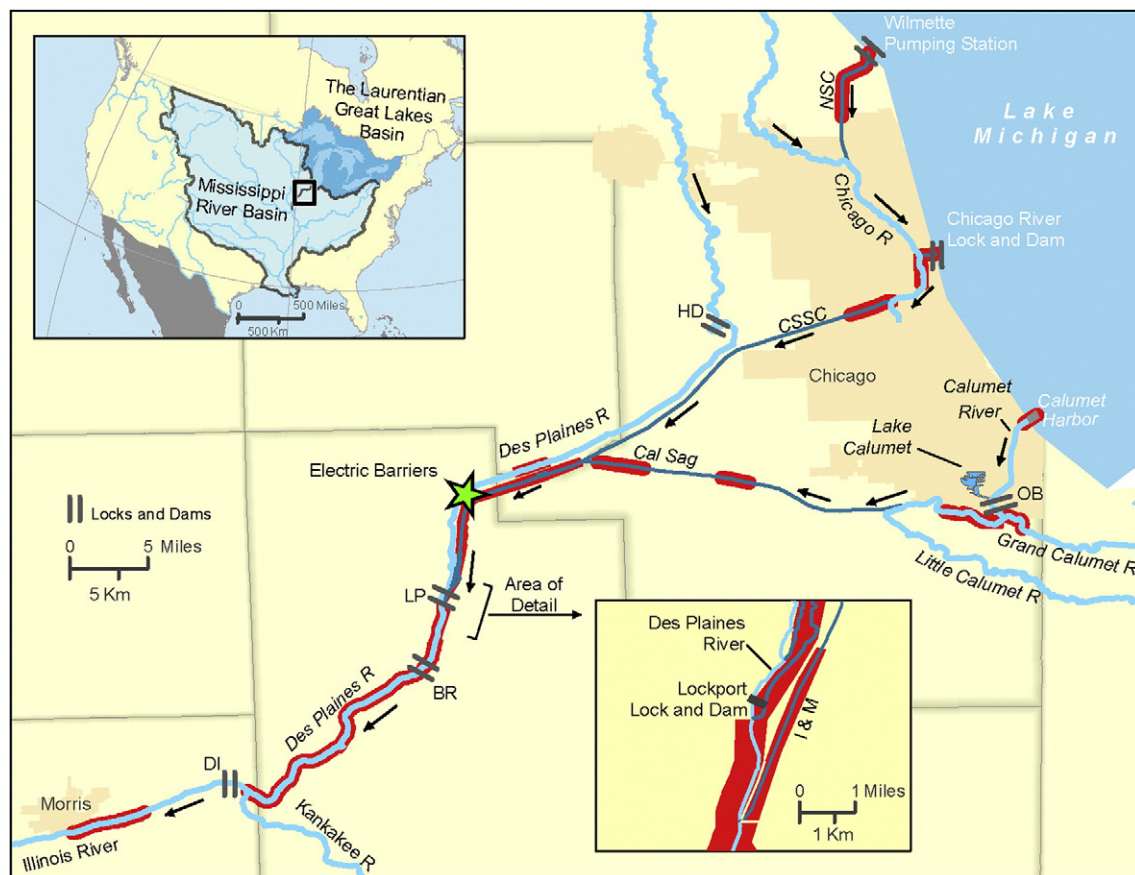


Fig. 1. Asian carp DNA detections (red) in the Chicago waterways upstream and downstream of the electric fish barriers in 2009 and 2010. Jerde et al. (2011) report 32 positive detections of eDNA from bighead carp and 26 detections of silver carp eDNA upstream of the electric barriers, including one silver carp eDNA detection in Calumet Harbor on Lake Michigan. Silver carp eDNA was also detected in the Chicago River in downtown Chicago and in the river's North Shore Channel, both less than 1 km from Lake Michigan. The waterways in Chicago connect downstream to the Des Plaines River which joins the Illinois River, a major tributary of the Mississippi River. There are locks and dams at Dresden Island (DI), Brandon Roads (BR), Lockport (LP), O'Brien (OB), Chicago River, Wilmette Pumping Station, and a low, notched dam, Hoffman Dam (HD), on the Des Plaines River. In Asia, bighead carp range north to 47° latitude, silver carp to 54° north. Map by S.R. Mysorekar, The Nature Conservancy, with DNA data from Jerde et al. (2010 and 2011).

in rivers as far north as 47° latitude, which equates in North America to the latitude of Lake Superior, or about 100 miles north of Lake Huron and almost 300 miles north of Lake Ontario. The native range of silver carp extends to 54° north, which cuts across the southern basin of Hudson Bay (Kolar et al., 2010). Twenty-two tributaries on the United States side of four Great Lakes are at least 100 km long and may have sufficient current velocity to keep Asian carp eggs in suspension long enough to hatch (Kolar et al., 2010). Water velocities and other factors in the tributaries are currently being assessed by the same group of researchers. Reports also exist of bighead and silver carp spawning in stagnant backwater environs, and fry being found in 50–55 °F (10–12 °C) water (personal communication, Mark Pegg, Illinois Natural History Survey, cited in Mandrak and Cudmore (2004)). Therefore, successful Asian carp reproduction may be possible in many smaller, shorter tributaries to the Great Lakes where oxygenated sand and gravel substrates occur.

Will Asian carps harm the Great Lakes?

Those who believe that too much is being made of an Asian carp invasion of the Great Lakes downplay the risk, claiming Asian carp will simply join the many species that are now accommodated by the Great Lakes ecosystem. For half a century fisheries biologists have struggled to minimize the damage wrought by a series of biological invasions [e.g., the sea lamprey, *Petromyzon marinus*; alewife, *Alosa pseudoharengus*; zebra and quagga mussels, *Dreissena polymorpha* and *D. rostriformis bugensis*; and most recently, fish diseases (e.g., viral

hemorrhagic septicemia, *Ichthyophonus hoferi*] (Fahnenstiel et al., 2010; Mills and Leach, 1993). These invaders have seriously damaged recreational and commercial fisheries, increased costs for natural resource management, severely impacted businesses dependent on recreation, clogged water intake systems, and fundamentally altered the food webs in most of the Great Lakes. Ship-borne invasive species (e.g., zebra mussels) alone are estimated to have cost raw water users, sport and commercial fisheries, and wildlife watchers on the U.S. portion of the Great Lakes over \$200 million annually through 2006 (Lodge and Finnoff, 2008).

There are only two examples of successful management of harmful invasive aquatic species in the Great Lakes, and both have had significant economic and ecological costs. Sea lamprey abundance in the Great Lakes is controlled by barriers, traps, periodic applications of a toxicant in their spawning areas, and release of sterile males, at a cost of \$22.8 million in 2008 and a projected cost of \$29.7 million in 2010 (Great Lakes Fishery Commission, 2008). The barriers and toxicants have some negative effects on non-target species, but the effects are considered acceptable by fishery managers in return for protecting highly valued fishes. Populations of alewife have been substantially reduced in the upper Great Lakes, first through predation by intentionally introduced salmon and now by competition from unintentionally introduced mussels that have reduced zooplankton populations. Unfortunately, zooplankton is essential not only to alewives but also to early life stages of highly-valued commercial and sport fishes (Fahnenstiel et al., 2010; Shuter and Mason, 2001).

Introduction of Asian carps, which are efficient plankton feeders throughout their life spans, would further deplete the base of the already-stressed food webs in the Great Lakes. After Asian carp populations exploded in the Illinois River, the condition factor of two native planktivores, the bigmouth buffalo (*Ictiobus cyprinellus*) and gizzard shad (*Dorosoma cepedianum*), declined, presumably as a result of competition for food (Irons et al., 2007). There is no species-specific approach yet available to control the Asian carps, and previous experience with lampreys demonstrates that control measures are likely to be costly and have some unavoidable side effects. It is better to prevent invasions than attempt to manage a harmful species after invasion.

Potential harm to biodiversity in the Mississippi River Basin

Recent media reports have focused on the threat to the Great Lakes posed by the Asian carps, and little attention has been paid to species in the Great Lakes that are potential invaders of the Mississippi Basin, including the 10 species mentioned by Jerde et al. (2010a). The 10 include two fishes, five plants, and three crustaceans. The fish-hook waterflea (*Cercopagis pengoi*), is a planktonic crustacean that preys on other zooplankton, thereby competing with larval and small fishes, while avoiding predation itself because of its long tail spine. The Eurasian ruffe (*Gymnocephalus cernuus*) is a 4–6-inch (10–15 cm), spiny fish that is likely to compete with native fishes for food. In terms of sheer number of endemic species, there is actually more to lose in the Mississippi than in the Great Lakes.

The Mississippi River Basin has the highest diversity of freshwater fishes (260 species) known for any region at comparable latitudes (Fremling et al., 1989; Smith, 1981). The diversity is especially high in tributaries of the Tennessee, particularly among shiners and minnows (Family Cyprinidae) and darters (Family Percidae). European gobies and other small invasive fishes that are already in the Great Lakes can move downstream and then upstream into very small tributaries. For instance, the round goby (*Apollonia melanostomus*) already moved through the Chicago canals into the upper Illinois River. Since gobies seek the same habitats and food sources as many darters, they are very likely to compete with the native species.

North America is the world center of biodiversity for freshwater mussels with 297 recorded species, most of which occur in the Mississippi River and its tributaries (Pennak, 1989). Unfortunately, 72% of the North American mussels are currently listed as endangered, threatened, or of special concern (Master, 1990; Williams et al., 1992). The introduction and spread of invasive mollusks (such as the zebra and quagga mussels, which probably entered the Mississippi through the Chicago waterways) have contributed to the decline of native mussels (Master, 1990). The local extirpations of native mussels in the western basin of Lake Erie and in Lake St. Clair bodes ill for the native mussels that are endemic to the Mississippi Basin (Nalepa et al., 1996; Ricciardi et al., 1998).

Conclusions and recommendations

The electric barriers have not been fully effective on Asian carp and will not work on organisms or propagules that drift downstream; eDNA evidence suggests silver and bighead carp are in the Chicago waterways well upstream of the electric barriers (Jerde et al., 2010b). Based on our current understanding of Asian carp dietary and habitat requirements it is unlikely they would be limited by food or habitat in the entire Great Lakes basin. The addition of two more species of plankton feeders to the Great Lakes would adversely affect an already stressed food base. There are more invasive species besides the Asian carps that could cause species extinctions, declines of valuable fisheries, and other economic losses if they pass between the Great Lakes and Mississippi basins via the Chicago connection. It is imperative to stop the exchange of invasive species as quickly as possible.

In response to the delays in the authorized study by the USACE, state elected and appointed officials on the Great Lakes Commission

and mayors of Great Lakes cities have secured funding from foundations to begin evaluating the engineering feasibility and estimated cost of alternatives for separating the two basins, with final recommendations to be presented in January 2012 (Great Lakes Commission, 2011). These evaluations do not obviate the need for a feasibility study by the USACE that includes separation, because the USACE is the only agency with the Congressional authority to implement whichever alternative is finally selected.

Hydrologic separation is the only option which closes the aquatic connection between the two basins and does not require continuous operation and maintenance of various technologies that have some risk of failure. The one-time, capital cost to separate the two basins is widely acknowledged to be high, and the outstanding question is whether the costs are justified given the significant risk of future ecological damages and long-term economic losses to the region. The pending legislation needs to be passed, so the public and their elected officials can evaluate the costs and relative risks based upon the best scientific information and engineering technology available.

References

- Blume, L., Darling, J., Vazquez, M., Chandler, J.S., 2010. Laboratory Audit Report of the Lodge Laboratory Department of Biological Sciences University of Notre Dame. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.
- Cooke, S., Hill, W.R., 2010. Can filter-feeding Asian carp invade the Laurentian Great Lakes? A bioenergetic modeling exercise. *Freshwater Biol.* 55, 2138–2152.
- Dettmers, J.M., Boisvert, B.A., Barkley, T., Sparks, R.E., 2005. Potential Impact of Steelhulled Barges on Movement of Fish Across an Electric Barrier To Prevent the Entry of Invasive Carp into Lake Michigan. Aquatic Ecology Report 2005/14, Illinois State Natural History Survey, Urbana, IL.
- Drake, J.M., Lodge, D.M., 2006. Allee effects, propagule pressure and the probability of establishment: risk analysis for biological invasions. *Biol. Invasions* 8 (2), 365–375.
- Fahnenstiel, G., Pothoven, S., Carrick, H., 2010. The lower food web of Lake Michigan: Long-term trends and the Dreissenid impact. *J. Great Lakes Res.* 36 (Supplement) 3, 1–4.
- Ficetola, G.F., Miaud, C., Pompanon, F., Taberlet, P., 2008. Species detection using environmental DNA from water. *Biol. Lett.* 4, 423–425.
- Finster, J., 2007. Investigating Injurious Species Introductions as Environmental Crimes, thesis. Michigan State University, East Lansing, MI.
- Flesher, J., 2010. Scientists: Mussels May Leave Carp Nothing To Eat. AP wire service, 29 September 2010. <http://www.channel3000.com/money/25205045/detail.html>.
- Frede, L., 2010. Human Introduction Confirmed in Asian Carp Discovery. Un-Lock Our Jobs, Chemical Industry Council of Illinois, Springfield, IL, 5 August 2010. <http://www.unlockourjobs.org/2010/08/05/press-release-human-introduction-confirmed-in-asian-carp-discovery/>.
- Fremling, C.R., Rasmussen, J.L., Sparks, R.E., Cobb, S.P., Bryan, C.F., Clafin, T.O., 1989. Mississippi River fisheries: a case history. In: Dodge, D.P. (Ed.), Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences 106. Department of Fisheries and Oceans, Ottawa, pp. 309–351.
- Golowski, D., 2010. Don't Fear Asian Carp Ohio State University Professor Says. Columbus Dispatch, 5 September 2010, p. C9.
- Great Lakes Commission, 2011. Lead Contractor Selected for Study Initiative to Modernize the Chicago Waterway System and Protect the Great Lakes from Asian Carp. Great Lakes Commission, Ann Arbor, MI. <http://www.glc.org/announce/11/01waterway.html>. 11 January 2011.
- Great Lakes Fishery Commission, 2008. Program Requirements and Cost Estimates Fiscal Year 2010. http://www.glfsc.org/staff/PRCE_10.pdf.
- Hill, L., 2000. The Chicago River: a Natural and Unnatural History. Lake Claremont Press, Chicago.
- Irons, K.S., Sass, G.G., McClelland, M.A., Stafford, J.D., 2007. Reduced condition factor of two native fish species coincident with invasion of non-native Asian carps in the Illinois River, U.S.A. *J. Fish Biology* 71, 258–273 Suppl. D.
- Jerde, C.L., Barnes, M.A., McNulty, J., Mahon, A.R., Chadderton, W.L., Lodge, D.M., 2010a. Aquatic Invasive Species Risk Assessment for the Chicago Sanitary and Ship Canal. University of Notre Dame, Center for Aquatic Conservation, Notre Dame, IN <http://switchboard.nrdc.org/blogs/tcmar/AIS%20Risk%20Assessment%20for%20CSC%202010.pdf>.
- Jerde, C.L., Mahon, A.R., Chadderton, W.L., Lodge, D.M., 2010b. Final Report: Environmental DNA surveillance of Asian carps in the Chicago Sanitary and Ship Canal. U.S. Army Corps of Engineers, Environmental Laboratories, Cooperative Environmental Studies Unit, Vicksburg, MS.
- Jerde, C.L., Mahon, A.R., Chadderton, W.L., Lodge, D.M., 2011. "Sight-unseen" detection of rare aquatic species using environmental DNA. *Conserv. Lett.* 4, 150–157. <http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2010.00158.x/pdf>.
- Kolar, C.S., Chapman, D., Courtenay, W.R., Housel, C.M., Williams, J.D., Jennings, D.P., 2010. Asian Carps of the Genus *Hypophthalmichthys* (Pisces, Cyprinidae)—A Biological Synopsis and Environmental Risk Assessment. US Fish and Wildlife Service, Washington, DC. www.fws.gov/contaminants/OtherDocuments/ACBSRAFinalReport2005.pdf.

- Lodge, D., Finnoff, D., 2008. Annual Losses to Great Lakes Region by Ship-borne Invasive Species at least \$200 Million. Center for Aquatic Conservation, University of Notre Dame, Notre Dame, IN.
- Mandrak, N.E., Cudmore, B., 2004. Risk Assessment for Asian Carps in Canada. Research Document 2004/103, Canadian Science Advisory Secretariat, National Capital Region, Fisheries and Oceans, Ottawa, Ontario. http://www.dfo-mpo.gc.ca/CSAS/DocREC/2004/RES2004_103_e.pdf.
- Master, L., 1990. The imperiled status of North American aquatic animals. *Biodivers. Netw. News* 3 (1–2), 7–8.
- McCloud, C., 2010. Testing Complete on Asian Carp Found in Lake Calumet. Illinois Department of Natural Resources, Springfield, IL. <http://www.dnr.illinois.gov/PressRelease/LakeCalCarp-testscomplete-aug2010.pdf>. 5 August 2010.
- Mills, E.L., Leach, J.H., 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. *J. Great Lakes Res.* 19 (1), 1–54.
- Nalepa, T.F., Hartson, D.J., Gostenik, G.W., Fanslow, D.L., Lang, G.A., 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to Dreissena polymorpha in eight years. *J. Great Lakes Res.* 22, 354–369.
- Pennak, R.W., 1989. Fresh-water Invertebrates of the United States: Protozoa to Mollusca. John Wiley and Sons, New York.
- Ricciardi, A., Neves, R., Rasmussen, J.B., 1998. Impending extinctions of North American freshwater mussels (Unionoidea) following the zebra mussel (*Dreissena polymorpha*) invasion. *J. Anim. Ecol.* 67, 613–619.
- Shuter, B.J., Mason, D.M., 2001. Exotic Invertebrates, Food-Web Disruptions, and Lost Fish Production: Understanding Impacts of Dreissenid and Cladoceran Invaders on Lower-Lakes Fish Communities and Forecasting Invasion Impacts on Upper Lakes Fish Communities. Report to the Board of Technical Experts, Great Lakes Fishery Commission, Ann Arbor, MI. http://www.glf.org/staff/fweb_whitepaper.pdf. viewed 24 April 2011.
- Smith, G.R., 1981. *Ann. Rev. Ecol. Syst.* 12, 163.
- Smith, G., Vandermeer, J., 2010. The Asian carp is a red herring. *Lansing State J.* http://www.lsa.umich.edu/eeb/news/pdfs/smith_vandermeer_lsjsilver_carp_editorial.pdf. 28 February 2010.
- Stanek, S., 2010. The carp are coming, the carp are coming, the carp are already here. *Chicago Daily Observer*, Chicago, IL. <http://www.cdobs.com/archive/featured/the-carp-are-coming-the-carp-are-coming-the-carp-are-already-here/>. July 2010.
- U.S. House, 2011. Stop Asian Carp Act. H.R. 892, 112th Congress, Washington, DC. <http://thomas.gov/cgi-bin/query/z?c112:H.R.892>.
- U.S. Senate, 2011. Stop Asian Carp Act of 2011. S. 471, 112th Congress. Senate Environment and Public Works Committee, Washington, DC. <http://thomas.gov/cgi-bin/query/z?c112:S.471>.
- USACE, 2010a. Dispersal Barrier Efficacy Study, Dispersal Barrier Bypass Risk Reduction Study and Integrated Environmental Assessment. U.S. Army Corps of Engineers, Chicago District, Interim Report I, Chicago, IL. http://www.lrc.usace.army.mil/pao/ANS_DispersalBarrierEfficacyStudy_Interim_I_FINAL.pdf. January 2010.
- USACE, 2010b. Fish Dispersal Deterrents, Illinois and Chicago Area Waterways Risk Reduction Study and Integrated Environmental Assessment. U.S. Army Corps of Engineers, Chicago District, Interim Report IIIA, Chicago, IL, pp. 28–29. http://www.lrc.usace.army.mil/pao/02june2010_InterimIIIA.pdf.
- USACE, 2010c. Great Lakes and Mississippi River Interbasin Study. U.S. Army Corps of Engineers, Chicago District, Chicago, IL. <http://www.lrc.usace.army.mil/pao/GLMRIS-StudySummary-08Nov10.pdf>.
- Water Resources Development Act, 2007. Public Law 110–114, Sec. 3061(d).
- Williams, J.D., Warren, M.L., Cummings, K.S., Harris, J.L., Neves, R.J., 1992. Conservation status of the freshwater mussels of the United States and Canada. *Fisheries* 18 (9), 6–22.