Chapter 10

Aquatic Nuisance Species

Zebra Mussel, Detroit River
Photograph by: Center for Great Lakes and Aquatic Sciences

Lake Superior Lakewide Management Plan
2000

Chapter 10 Contents

Addendum

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EXECUTIVE SUMMARY

An increasing concern for environmental policy makers in the Great Lakes region is the invasion of aquatic habitats by nonindigenous (non-native) species. Nonindigenous species, also known as non-native and exotic species, are those that do not naturally exist in an environment and have been introduced by human activity, either intentionally or unintentionally. Aquatic nuisance species (ANS) in the Great Lakes have both ecological and economic impacts. ANS have seriously altered and disrupted Great Lakes ecosystems, due to a lack of co-evolved parasites and predators to keep their populations under control. The ANS have the ability to out-compete native species for food and habitat, and in the most severe cases, to displace native species entirely.

The ANS that are currently the greatest threat to the integrity of the Lake Superior ecosystem include alewife, Eurasian water milfoil, purple loosestrife, rainbow smelt, round goby, ruffe, sea lamprey and zebra mussel. A discussion of each of these ANS threats is provided along with a brief discussion of noxious terrestrial invasive species.

Various federal programs have been implemented in an attempt to check the negative impact that nonindigenous species are having on the Great Lakes. Foremost is the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), which provides federal legislative support for programs aimed at ANS prevention and control. Under the NANPCA, the Great Lakes became the first area where ballast water regulations were imposed. A variety of other programs to help prevent and control the spread of ANS have been established under the authority of the NANPCA, including the Aquatic Nuisance Species Task Force, Comprehensive State Management Plans and the Great Lakes Panel on Aquatic Nuisance Species. In 1996, the NANPCA was reauthorized through the National Invasive Species Act (NISA). President Clinton reinforced the need to stop the further introduction of nonindigenous species when he signed the Invasive Species Executive Order on Feb. 3, 1999.

Other programs implemented to help stem the invasion by nonindigenous species include the Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species, model guidance, The Great Lakes Ballast Water Technology Demonstration Project (GLBTDP), U.S. Coast Guard programs, Canadian Coast Guard programs, tribal programs, and Canadian programs. In an effort to have ballast water more stringently regulated by the U.S. government, the Pacific Environmental Advocacy Center (PEAC) filed a petition with EPA requesting that EPA repeal its exemption of ballast water from National Pollutant Discharge Elimination System (NPDES) regulation under the Clean Water Act (CWA).

The management activities of ANS have four distinct components: educational outreach, detection and monitoring efforts, prevention activities and control activities. Within each of

these components are a variety of measures that can and/or should be taken. Of particular concern is the need to design and implement effective ballast management programs and resolution of the "no ballast on board" (NOBOB) issue.

Experts disagree about the relative importance of prevention and control. Effective control in aquatic systems is often impossible, but the impacts of ANS merit an attempt. At least partial success has been achieved in control programs with the sea lamprey, ruffe, and purple loosestrife. Everyone agrees prevention is best, because once a species invades a new habitat, it is virtually impossible to eradicate it from that environment. This need for adequate prevention explains why such an emphasis is placed on restricting and regulating ballast water discharges in an attempt to stop further introductions of ANS.

Finally, additional efforts need to be explored and implemented to stop further introduction and spread of nonindigenous species. Examples of such efforts are suggested in the policy recommendations and needed actions section and include the need for better identification of possible future invaders, the need to encourage interjurisdictional cooperation and information sharing, the necessity to devise new technology to deal with the threat of ANS, and the need to improve ballast water management.

10.0 ABOUT THIS CHAPTER

This section was developed primarily from the draft document entitled *Briefing Paper for Great Lakes Nonindigenous Invasive Species Workshop* for the October 1999 meeting, and also reflects a number of comments received from expert reviewers.

10.1 PROBLEM STATEMENT

Invasion of aquatic habitats by nonindigenous (non-native) species has become an increasing concern for environmental policy makers in the Great Lakes region. Nonindigenous species, also known as non-native and exotic species, are those that do not naturally exist in an environment and have been introduced by human activity, either intentionally or unintentionally. Some nonindigenous species are disruptive to the new aquatic environment because they lack natural predators to curtail their expansion. These species are referred to in this section as aquatic nuisance species (ANS). ANS compete with native species for food, territory and breeding areas and often end up threatening the existence of the native species. For example, the Eurasian ruffe colonized the nearshore waters of western Lake Superior in the late 1980s (Pratt and others 1992), and became very abundant in this favorable habitat, raising concerns about its competition with native species (Ruffe Task Force 1992, Bronte and others 1998). Zebra mussels and round gobies have caused pervasive impacts in the other Great Lakes and may yet have serious impacts in Lake Superior. In the Great Lakes ecosystem, this biological form of pollution is considered by some to be just as threatening to environmental health as is pollution caused by chemical contaminants. Therefore, ANS deserve the attention and resources needed to address the problem before further harm is done.

Since the 1800s, more than 139 nonindigenous aquatic organisms have become established in the Great Lakes, including 25 species of fish (Mills and others 1993). Of the 94 fish species known to inhabit Lake Superior and its tributaries, 18 are nonindigenous (U.S. Fish and Wildlife Service [USFWS] 1995). Approximately 10 percent of the nonindigenous species introduced into the Great Lakes can be classified as nuisance species; all have had significant impacts, both economic and ecological. Unintentional introductions of these species into the Great Lakes have occurred primarily through the transport of ballast water carried in ships engaging in international trade, but other practices, such as the building of canal systems within the Great Lakes basin, fish stocking practices, angling, recreational boating and aquarium releases have also contributed to the problem. The rate of introductions has increased; nearly a third of the nonindigenous organisms found in the Great Lakes have been introduced since the opening of the St. Lawrence Seaway in 1959. Once introduced to the Great Lakes, nonindigenous species spread inland, frequently by way of barges, recreational watercraft, bait buckets, fish stocking, and other human-assisted transport mechanisms. The spread of species between ecosystems is usually hampered by natural barriers such as the open ocean, different salinity levels, and the inability of organisms to reach hospitable ecosystems on their own. However, shipping allows many organisms to bypass these natural barriers through the transportation of nonindigenous species in the ballast water of seagoing vessels involved in international trade. In summary, shipping disrupts the customary checks and balances in place to prevent introductions of nonindigenous species and the subsequent degradation of ecosystems (U.S. Coast Guard [USCG] 1999).

One of the impacts of an established nonindigenous species is the promotion of instability and unpredictability in stable ecosystems, and the loss of diversity in biotic communities (Mills and others 1993). ANS can also be responsible for extinctions of native species and ecological degradation of the Great Lakes basin.

ANS have had, and continue to have significant economic effects on the commercial fishing industry, agriculture, tourism, sport fishing, recreation, utilities and other industries. The U.S. Office of Technology Assessment (OTA) delivered a 1993 Report to Congress entitled *Harmful Non-Indigenous Species in the United States,* which attempted to measure the economic impact of nonindigenous plants, animals and microbes on aquatic environments. The report assessed over 4,500 non-indigenous nuisance species, including 2,000 plants, 2,000 insects, 142 terrestrial invertebrates, 91 mollusks and 70 species of fish. Economic costs are hard to accurately estimate since no federal agency comprehensively compiles such statistics. Ecological damage and other nonmarket impacts were not assessed; the report stated, however, that even when such losses were estimated, cost assessments of losses tended to be underestimated (OTA 1993).

Another estimate of economic losses due to nonindigenous species was made in a 1999 study by Pimental and others from Cornell University. The study documented over 50,000 nonindigenous species in the U.S. with an estimated annual economic cost of $138 billion (Pimental and others 1999). Included among the cost estimates were control costs, property value damage, health costs and various other expenses. Pimental and others also indicated that if monetary values could be assigned for ecological losses, the economic cost would be much higher than the $138 billion estimated. Given the high ecological and economic costs to the Great Lakes, heightened vigilance is necessary for the prevention and control of ANS.

10.2 STATUS AND CURRENT CONDITIONS OF AQUATIC NUISANCE SPECIES

In the Great Lakes basin there are a number of ANS believed to constitute the greatest threat to native species. As a result, these ANS have been targeted for initial action. Lake Superior related information has been included in this section to indicate the threat to this particular ecosystem. The ANS discussed below (both flora and fauna) are listed in alphabetical order and are not prioritized in terms of potential or known impacts.

Alewife

Alewife (*Alosa pseudoharengus*), a fish closely related to the Atlantic herring (*Clupea harengus harengus*), invaded the Great Lakes around 1953 after the building of the canal systems. Alewives are known to prey upon the pelagic larvae of native fish species and to suppress recruitment of those species. While they were once a serious threat to native fish and recreation, this threat was mitigated with the introduction of nonindigenous salmonid species into the Great Lakes as a biological control for alewife populations. However, consumption of alewives by the salmonid species has had an unintended counter-effect on these predators, since alewives are also implicated as a putative causal agent for early mortality syndrome of salmonine fishes, which results in elevated mortality of newly-hatched salmonine larvae as a result of thiamine deficiency. Alewives have a high concentration of the enzyme thiaminase, which degrades thiamine, and a diet rich in alewives is believed to lower thiamine levels in eggs of female salmonine predators.

Viewpoints on the effects of alewives on native fishes differ among biologists, but evidence does at least show the potential for negative interactions in both the upper lakes and lower lakes. Alewife intolerance to cold temperature (i.e., moderate to harsh winters) has been correlated with improved recruitment of native percids in Lake Erie. There have been efforts in recent years to protect alewife populations through control of commercial fisheries and reduced salmon stocking. Alewives are still a threat to native species (nonindigenous species too) because they have been found to prey on eggs and fry of lake trout, compete for food, and most importantly contain thiaminase, which, as noted, has been linked to early mortality syndrome in their predators such as lake trout, walleye, and salmon (Eshenroder and others in Great Lakes Fishery Commission Technical Report 64). While the alewives are not currently a major threat in Lake Superior, the species is poised to enter the Lake Superior ecosystem from other Great Lakes if its progress is not checked.

Eurasian Watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*) forms masses of vegetation in nutrient-rich lakes (usually inland). It crowds out native aquatic vegetation and interferes with water recreation. It is unclear at this point how much of a threat the Eurasian watermilfoil poses to the Lake Superior ecosystem.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) is a plant native to Europe that was first brought to North America in the early 1800s. Purple loosestrife is now found throughout much of the United States and Canada. It has invaded wetland areas, where it has a competitive advantage over native plant species, and has formed habitats that are unsuitable for native wetland animals. Control measures used on purple loosestrife include physical removal, chemical treatment, and biological control through introduction of natural predators, European beetles and weevils.

Rainbow Smelt

Rainbow smelt *(Osmerus mordax),* native to the Atlantic coast, entered Lake Superior around 1930. Rainbow smelt populations grew rapidly during the 1950s and 1960s, and became the dominant prey species for lake trout in Lake Superior (Dryer and others 1965, Conner and others 1993). Rainbow smelt became the principal forage fish for lake trout and other top predators and have been implicated as a competitor for the native lake herring, whose populations collapsed during the buildup of the smelt population. The rainbow smelt population continued to grow until the late 1970s and then declined greatly due to heavy predation by trout and salmon, reaching all-time low levels of abundance in the early 1980s. Rainbow smelt prey upon the larvae of native fish and eat a diet that broadly overlaps that of other native cisco species. Smelt are the preferred food for predator fish, and have profoundly changed the flow of energy through the Lake Superior fish community. Rainbow smelt also contain thiaminase (about half as much as alewives) and therefore have a negative impact on the survival rate of newly-hatched salmonine larvae. Fishery management agencies in the Lake Superior basin have agreed that rainbow smelt is an undesirable species that should not be protected from fishing.

Round Goby

The round goby (*Neogobius melanostomus*) is a small, bottom-dwelling, soft-bodied fish. It is native to the Black and Caspian Seas, was first detected in the St. Clair River in 1990, and by 1995 had spread to four of the five Great Lakes. The round goby was discovered in Lake Superior in the St. Louis River Estuary in 1995. It is believed that round gobies were introduced to the Great Lakes through ballast water transfer. The goby is currently poised to enter almost half the United States through connected waterways unless its progress can be halted. The round goby is currently found 44 miles downstream in the Illinois Waterway, which connects to the Mississippi River.

Round gobies are particularly threatening because they are aggressive, territorial, competitive for food, spawning, and shelter areas, highly tolerant of a variety of environmental conditions, feed on eggs and fry of native fish, and have a large body size compared to similar bottom-dwelling fish species. On the beneficial side, gobies eat large quantities of small zebra mussels, up to 78 mussels per day in laboratory settings. Because gobies eat zebra mussels and in turn are eaten by many piscivorous fishes, they provide a conduit from mussel tissue to fish tissue that was previously less available in a goby-free environment. Contaminant transfer from zebra mussels to highly-valued fish species is an issue. Research is underway to investigate the severity of this problem.

Ruffe

The ruffe (*Gymnocephalus cernuus*), a small perch-like Eurasian fish, was first detected in the estuary of the St. Louis River in western Lake Superior in 1986 and became very abundant in the favorable habitat of the nearshore waters, raising concerns about competition with native species (Ruffe Task Force 1992, Bronte and others 1998). It is believed to have been transported there in the ballast water of seagoing vessels, as Duluth is a major port on Lake Superior. By 1991, the ruffe was the most abundant species in the St. Louis River estuary. The ruffe is also now found in Lake Huron at Alpena Harbor, Michigan, very likely the result of transport in ballast water of interlake shipping. The Great Lakes Fishery Commission estimates the European ruffe could cause annual losses of $105 million annually if is not controlled. A control program for ruffe was approved in 1995 and has been successful in delaying the spread of ruffe in the Great Lakes and inland waters.

Sea Lamprey

The sea lamprey (*Petromyzon marinus*) is an eel-like, jawless fish that attaches itself to the body of a fish and sucks blood and tissue from the wound. The lamprey is native to coastal regions on both sides of the Atlantic and was first noticed in Lake Ontario in the 1830s. Originally, Niagara Falls served as a natural barrier to keep sea lampreys out of the upper Great Lakes. However, when the Welland Canal was constructed in 1829 for the shipping industry, a new route for sea lampreys was opened and the invasion of the upper Great Lakes began.

In 1921 the lamprey was discovered in Lake Erie, in 1936 in Lake Michigan, in 1937 in Lake Huron and finally in Lake Superior in 1938. The sea lamprey is considered the most devastating of all ANS to have infested the Great Lakes. A subsequent explosion in the sea lamprey population caused extinction in lake trout in all the Great Lakes but Lake Superior. It is only through control and restocking activities that lake trout populations have recovered. Even today, the Fishery Commission has declared that more fish are taken by sea lamprey every year than by commercial and sport fishing combined. An international control program under the Great Lakes Fishery Commission has successfully suppressed sea lamprey populations since about 1960. This control program is the oldest control program in existence in the U.S., and yet all efforts have still been unable to eradicate the species from the Great Lakes ecosystem.

Zebra Mussel

The zebra mussel (*Dreissena polymorpha*) is native to the Caspian Sea region and quickly spread throughout Europe before the Industrial Revolution. It is believed to have entered the Great Lakes region in 1985 or 1986 through ballast water discharge. By 1989, zebra mussels could be found in all of the Great Lakes, as well as many inland lakes. Under the right conditions, zebra mussels reproduce quickly, are very prolific, and are very tolerant to a wide range of environmental conditions. Environmental conditions in the Lake Superior basin have generally prevented reproduction by zebra mussels, though mild weather in recent years has apparently allowed reproduction to occur in the St. Louis Estuary.

Zebra mussels compete with native species for phytoplankton and zooplankton, are believed to contribute to the cycling of some contaminants, fundamentally alter the habitat and food webs, and are harmful toward native mussels to the extent that they kill native mussels by encrusting their shell so heavily that the native species cannot open to feed or breathe. Beyond their ecological effects, zebra mussels also create serious financial costs for facilities that draw water from the Great Lakes by clogging water intake systems. Although various methods are being explored, no effective means of control in natural aquatic systems has yet been found for zebra mussels in the Great Lakes.

Other Species

Several other species of concern have colonized in Lake Superior and/or tributaries. A summary of these species has been compiled for this chapter by Douglas A. Jensen, Exotic Species Information Center Coordinator at the University of Minnesota Sea Grant Program, Duluth and is listed in Addendum 10-A at the end of this chapter. For completeness, the previously mentioned species have also been included in the table.

10.3 TERRESTRIAL SPECIES

Even though the focus of this chapter is aquatic nuisance species, it bears mentioning that there are a number of terrestrial nuisance species that are threatening the biodiversity of the Lake Superior basin. These species include the following, in part excerpted from the article, *Weeds Gone Wild* by Jay Rendall:

Exotic Buckthorns

Exotic buckthorn *(Rhamnus cathartica* and *R. frangula)* has invaded plant communities from state parks to back yards. European or common buckthorn invades woodlands. Glossy or columnar alder-buckthorn is generally found on moist soils.

Exotic Honeysuckles

Exotic honeysuckles *(Lonicera tatarica, L. morrowii, L. maackii,* and the hybrid *L.* x *bella)* have been used as ornamentals for decades. Birds carry their seeds from formal landscapes to natural habitats, including grasslands, marshes, and woodlands. Once established, often with European buckthorn, honeysuckle can dominate the understory of woodlands.

Garlic-mustard

Garlic-mustard *(Alliaria petiolata)* spreads and dominates the ground flora in forests, replacing native woodland plants. Seedlings of this biennial herb germinate in early spring and by midsummer form a cluster or rosette of three or four leaves. In the spring of its second year, it flowers, sets seed, then dies. Floodwaters, wildlife, people's footwear, and off-road vehicles carry seeds to new sites. Management methods include hand removal, herbicide treatments, and repeated burning, though none can control large infestations. A long-term control using biological agents is being sought.

Leafy spurge

Leafy spurge *(Euphorbia esula)* is a plant that has roots that can extend 35 feet, grows through asphalt, and flings its seeds 15 feet. It invades prairies, roadsides, and pastures. Its deep root system enables it to survive dry conditions and resprout even after the foliage is destroyed. Control usually combines use of herbicides, prescribed fire, and mowing. Insects for biological control have been released at several hundred sites in the state of Minnesota by the U.S. and Minnesota departments of agriculture.

Reed canary-grass

European and cultivated strains of reed canary-grass *(Phalaris arundinacea)* were originally introduced as forage. This widely planted grass has also been used to establish cover on streambanks and wetland projects. Native plant populations are excluded after this species invades.

Spotted Knapweed

Spotted knapweed *(Centaurea maculosa* or *C. biebersteinii)* probably arrived here in alfalfa or hay seed from Europe and Asia. It reproduces solely by seed. Dry prairies, oak and pine barrens, and sandy ridges are likely natural habitats. Chemical control can be fairly effective, but cost is prohibitive. The USDA is conducting a biological control program, involving a root-mining beetle, two root-mining moths, and a flower moth, which has produced varying levels of success. Two species of seed-head-attacking flies have reduced seed production by 95 percent in experiments.

Asian Longhorned Beetle

The Asian Longhorned Beetle (*Anoplophora glabripennis)* is native to China, and is a hardwood tree pest. It is believed to have been imported to the U.S. in untreated wood used for pallets and packing materials. It was first discovered in the U.S. in 1996, and in a Chicago neighborhood in 1998. These beetles spread rapidly from tree to tree, killing trees by boring deep holes in them. There is no known method of eradicating the beetles short of destroying the infested trees. Due to its recent introduction into the Great Lakes basin, the extent of potential damage due to this non-native nuisance beetle has not yet been assessed, although hundreds of trees have already been destroyed in the Chicago area.

Gypsy Moth

The gypsy moth *(Lymantria dispar)* is plain-looking insect that people would not notice if it were not for its caterpillar stage. A female moth lays a cluster of eggs (called an egg mass) on or near trees, and each egg mass can hatch up to a thousand tiny caterpillars with a ravenous appetite for leaves. They feed on over 500 species of trees and shrubs. Oaks and alder are preferred broad-leafed trees. Douglas fir and western hemlock are favorite needle trees. A new crop of hungry caterpillars is hatched each year, at the end of April or early in May. By the time they are ready to pupate into the moth stage, they can attain a length of 2-1/2 inches, which is 20 times their original size. The relentless chewing can strip entire stands of trees of all their leaves. People exposed to the caterpillars hate them. The caterpillars' strands of silk, their droppings, the shreds of wasted leaves, and their very bodies make homes, yards, parks, and playing areas unattractive.

Suppression means preventing buildup of damaging gypsy moth populations to protect recreation areas, forested communities, and high-value timber stands in the established infestation in the northeast. This work is carried out by state agencies with help from USDA’s Forest Service.

Hemlock Woolly Aphid

Introduced into the Pacific Northwest in the 1920s, the hemlock woolly aphid *(Adelges tsugae)* was first reported in eastern Virginia in the early 1950s. Since then it has spread primarily northeastward and now occurs as far north as Connecticut and Rhode Island. The primary host is hemlock, with spruce being a possible secondary (alternative) host.

Immature nymphs and adults damage trees by sucking sap from the twigs. The tree loses vigor and prematurely drops needles, to the point of defoliation, which may lead to death. If left uncontrolled, the aphid can kill a tree in a single year. When not at serious risk to the tree, presence of the dirty white globular masses of woolly puffs attached to the twigs or base of needles reduces the value of ornamentals.

Application of insecticides is currently recommended for controlling the hemlock woolly aphid. Tree fertilization can result in more damage, as aphid populations are known to flourish on such trees. It is believed that this species originally came from Japan. Currently, researchers are investigating the prospects of identifying and importing natural enemies for use against this pest.

Pine Shoot Beetle

The pine shoot beetle (*Tomicus piniperda*), a serious foreign pest of pines, was discovered at a Christmas-tree farm near Cleveland, Ohio in July 1992. A native of Europe, the beetle attacks new shoots of pine trees, stunting the growth of the tree. The USDA's Animal and Plant Health Inspection Service (APHIS) has taken steps to prevent this insect from moving to major pine-tree production areas. APHIS, in cooperation with state officials, has quarantined 43 infested counties in Michigan, Indiana, Ohio, New York, Illinois, and Pennsylvania. Most of the beetle finds have been at Christmas-tree farms and pine-tree nurseries. The beetle prefers Scotch pine but will feed on most, if not all, species of pine. Although the beetle is slow moving, it could spread to other areas through the movement of Christmas trees, nursery stock, and pine logs.

In cooperation with state officials, APHIS is requiring the inspection of cut Christmas trees, pine nursery stock, and pine, logs, stumps, and lumber with bark attached before these regulated articles can move out of quarantined areas. Lumber and logs without bark attached are not regulated. Additionally, APHIS and cooperating officials are conducting wide-ranging detection surveys for the pest. State and federal scientists are working with the affected industries to develop appropriate control strategies.

10.4 CURRENT PROGRAMS AND INFORMATION GATHERING EFFORTS

The prevention and control of ANS has global implications that require policies and programs at various levels of government. This section provides a brief overview of the role of major programs and responsible agencies addressing ANS. For a more detailed explanation of the responsibilities of each agency, see the *Briefing Paper for Great Lakes Nonindigenous Invasive Species Workshop*.

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA)

The NANPCA provides U.S. federal legislative support for programs aimed at ANS prevention and control. The Act was enacted by Congress in recognition of the fact that the ANS threat required well-coordinated research, monitoring and prevention programs at both the regional and national levels to be successful. Under the NANPCA, the Great Lakes region became the first area where ballast water regulations were imposed.

Aquatic Nuisance Species Task Force (ANS Task Force)

The ANS Task Force was established under Section 1201 of the 1990 NANPCA legislation and is an intergovernmental organization, made up of representatives from seven federal agencies, dedicated to the prevention and control of ANS and the implementation of the NANPCA. The main action of the ANS Task Force is the adoption of the cooperative ANS Program. The ANS Program seeks to prevent, detect, monitor, and control ANS.

National Invasive Species Act (NISA) of 1996

The NANPCA was reauthorized through the National Invasive Species Act of 1996. NISA expands the ballast management program to the national level, makes ballast water exchange mandatory in the Great Lakes and enhances other national monitoring, management, and control programs.

Executive Order on Invasive Species

President Clinton signed the Invasive Species Executive Order on February 3, 1999, to help complement and build upon existing federal authority to aid in the prevention and control of invasive species. President Clinton also proposed $28.8 million in support in the FY2000 budget. The Great Lakes region welcomes the attention the Executive Order has drawn to the effects of ANS on the region.

Great Lakes Panel on Aquatic Nuisance Species

Under the NANPCA, the ANS Task Force requested that the Great Lakes Panel on Aquatic Nuisance Species be convened in accordance with Section 1203 of the Act. The Great Lakes Panel also works for the prevention and control of ANS in the Great Lakes and is made up of representatives from the United States and Canada, as well as the eight Great Lakes states, Ontario, Quebec, and various regional and local agencies.

Comprehensive State Management Plans

Comprehensive State Management Plans are suggested for states seeking grants for ANS prevention and control under Section 1204 of NANPCA. Comprehensive State Management Plans are to identify management practices and measures for the prevention and control of ANS infestations in an environmentally sound manner. State management plans are submitted to the

ANS Task Force for approval. Upon approval, states are eligible for grant money upon the recommendation of the Task Force. Tribes and interstate plans are also eligible to receive grant money. Thus far, plans have been approved for the Great Lake states of Illinois, New York, Michigan, Ohio, and the St. Croix River basin; plans are currently being developed in Minnesota and Wisconsin.

Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species

The *Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species* is proposed for adoption by the governors of the Great Lakes states. It is an attempt to establish a formal policy agreement that articulates a vision for the Great Lakes basin. The Action Plan would be a good faith agreement among its signatories whose goal is the interjurisdictional cooperation and coordination of ANS prevention and control efforts.

Model Guidance

A plan has been developed by the Great Lakes Panel to help provide policy recommendations and needed actions for the Great Lakes community. The action is in the form of a model guidance, entitled *Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species: Model Guidance for the Great Lakes Jurisdiction*. This model guidance is a toolkit from which states, provinces, tribal authorities, and local entities may select the regulatory tools that are best suited to address the problems in their infested watersheds. The goal of this guidance is to provide interjurisdictional consistency to laws, regulations and policies to be used for ANS prevention and control efforts. It is hoped that this multi-watershed, interjurisdictional approach will facilitate cooperation in dealing with the problems caused by ANS.

U.S. Coast Guard Programs

There are many regulations governing ballast water in the Great Lakes. The USCG established both regulations and guidelines for the control of ANS to comply with the NISA in 1996. The rule established voluntary ballast water management guidelines for all waters of the U.S. and established mandatory reporting and sampling procedures for all vessels to help limit the further introduction of ANS through ballast water.

NISA also directed the USCG to work in conjunction with the Smithsonian Environmental Research Center (SERC) to develop a National Ballast Water Information Clearinghouse to help gather information and data concerning ballast water management and ballast-mediated invasions. The Clearinghouse was established in 1997 at SERC. The U.S. Coast Guard and the Clearinghouse are implementing a nationwide program, the National Ballast Survey (NABS), to measure ballast water management and delivery patterns for commercial vessels arriving in U.S. ports to help create a national database on ballast water.

The U.S. Coast Guard also continues to work with the International Maritime Organization to develop international instruments for ballast water management.

Canadian Coast Guard Programs

The Canadian Coast Guard has had guidelines in place since 1989 regarding the voluntary open ocean exchange of ballast water for ships carrying fresh water ballast and wanting to travel into the St. Lawrence Seaway and the Great Lakes. The same ballast water exchange rules became mandatory in 1993 in the U.S. A salinity of greater than 30 parts per thousand is required for the ballast water of all ships entering the Great Lakes system. The Canadian Coast Guard works in conjunction with the Department of Fisheries and Oceans, the Marine Safety Branch of Transport Canada, and the USCG to ensure that ballast water guidelines are being met. It is important that application of any ballast water management regime be applied consistently to all vessels entering the system and that agencies not discriminate against vessels coming from certain trades or countries.

Currently, a major concern for the Canadian Coast Guard is the "no ballast on board" (NOBOB) issue (see the section on Prevention Activities for a discussion of NOBOB) and, as a result, research money has been dedicated to help find a resolution for this problem.

PEAC Petition

The Pacific Environmental Advocacy Center (PEAC) filed a petition with EPA requesting that EPA repeal its exemption of ballast water from National Pollutant Discharge Elimination System (NPDES) regulation under the Clean Water Act (CWA). Under current EPA regulations, vessels are exempt from having to acquire an NPDES permit in order to discharge ballast water. The petitioners contend that vessels are point sources of pollutants, as defined under the CWA, and should be required to obtain permits to discharge ballast water into U.S. waters. PEAC contends that ballast water not only contains the traditional pollutants of toxins and sediments, but also carries large numbers of non-indigenous species, which the PEAC argue qualify as biological pollutants as defined by the CWA. Therefore, in order to protect U.S. waters and native ecosystems from the threat posed by the various pollutants in ballast water as intended by the CWA, PEAC argues for the removal of the ballast water exemption. EPA is currently conducting a study to determine how it could most effectively bring its authority under the CWA or other statutes to bear on the problem of invasive species in ballast water. That study is scheduled for release in the spring of 2000.

Tribal Programs

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) has been working since 1986 in conjunction with the USFWS on the Sea Lamprey Control (SLC) Program. This program, along with programs of other agencies, works to gather information on adult sea lamprey to help find approaches to control and reduce the lamprey population. Lampreys ascend into various tributary streams of Lake Superior during their May-June spawning run.

The GLIFWC is also involved in strategies to control purple loosestrife in wetland ecosystems. They have seen success in loosestrife control through their use of chemical and biological (herbivorous beetles) controls in infested areas. For example, by their estimations, their strategies have reduced loosestrife cover in Fish Creek Sloughs on Chequamegon Bay, Lake Superior, by well over 90 percent and have started to control loosestrife along the Highway 13 corridor. GLIFWC has performed surveys to determine loosestrife distribution and has prepared GIS maps illustrating distribution and relative abundance of purple loosestrife in the surveyed areas. Further research on control activities is being performed by GLIFWC staff under a grant funded by the Natural Resources Conservation Service (NRCS). In addition to allowing for research on purple loosestrife control activities, the NCRS funds were used in the development of education materials to increase awareness and solicit help from the general public in controlling the spread of purple loosestrife.

In addition to participation in sea lamprey and loosestrife control programs, GLIFWC also works with efforts to control the spread of ruffe and zebra mussels in Lake Superior, participates in a variety of programs advocating native species, works with the Great Lakes Panel on various activities, takes part in the Stop the Invaders community outreach program, and co-occupies an ex-officio seat on the ANS Task Force.

Another tribal program, the Chippewa/Ottawa Treaty Fishery Management Authority (COTFMA) was created to manage and regulate the treaty fishery sections of the Great Lakes, including southeastern Lake Superior. The Inter-Tribal Fisheries and Assessment Program (ITFAP) is a division of COTFMA which is responsible for conducting research, assembling catch statistics, and recommending harvest quotas. The ITFAP has also worked on projects in conjunction with the USFWS Sea Lamprey Control Station and participated in the Sea Lamprey Control Program. In addition, the COTFMA is a signatory to the PEAC petition to amend the Clean Water Act exemption on ballast water discharge. On the national level, COTFMA co-occupies an ex-officio seat on the ANS Task Force.

Canadian Programs

Several Canadian agencies are involved in exotic species programs on the Great Lakes. Impacts of exotic species on the ecosystem are monitored by the OMNR's Lake Management Units and the federal Department of Fisheries and Oceans. The OMNR also participates in the ruffe surveillance program and the ruffe control program and is a member of the Great Lakes Panel on Aquatic Nuisance Species. In partnership with the Ontario Federation of Anglers and Hunters, Ontario operates an Invading Species Hotline for the reporting and maintenance of a central registry of new exotic species sightings and range extensions. This program also serves as the center for Ontario's exotic species public awareness program and acts as a single window information source for the public. A volunteer zebra mussel monitoring program is also coordinated through this program. The Canadian Coast Guard works in partnership with the U.S. Coast Guard on ballast water management issues.

The Great Lakes Ballast Water Technology Demonstration Project (GLBTDP)

The Great Lakes Ballast Water Technology Demonstration Project (GLBTDP) was initiated in 1996 by the Northeast-Midwest Institute and the Lake Carriers Association to help provide the shipping industry with a tool box of options. The goal of the program was to evaluate and help improve the operational and biological effectiveness of filtration as a primary treatment method for treating ballast water. Part of the testing took place aboard an operating commercial vessel, the *M/V Algonorth*, and part on a stationary barge in Duluth Harbor. This filtration testing was completed in 1998 with funding from the Great Lakes Protection Fund and the state of Minnesota through the Legislative Commission on Minnesota Resources. Filtration showed promise as a means of removing organisms above 50 microns. However, secondary treatment following filtration will be necessary to address unicellular phytoplankton organisms, bacteria and viruses. A secondary treatment demonstration jointly funded by the Great Lakes Protection Fund and the U.S. EPA's Great Lakes National Program Office is scheduled to be conducted in the summer of 2000.

10.5 EDUCATIONAL OUTREACH

Various educational and outreach measures have been implemented in the Lake Superior basin to help raise public awareness of the threat posed by ANS. The Minnesota Department of Natural Resources (MN DNR), Minnesota Sea Grant, Ontario Ministry of Natural Resources, Ontario Federation of Anglers and Hunters, Michigan Sea Grant, Wisconsin Department of Natural Resources, Wisconsin Sea Grant, USFWS, and others provide literature to the public to help them identify ANS, suggest ways to stop the spread of ANS, and provide information about laws pertaining to ANS. The MN DNR has also placed an emphasis on inspecting boats and informing boaters who leave infested waters to drain water and remove ANS.

The Minnesota Sea Grant Program is also active in educating the public about the impacts of ANS on the Minnesota ecosystem. The National Sea Grant Program offers an even wider array of literature describing the threat of ANS. This educational material includes I.D. cards for various species which include a detailed picture and description of the species, the areas the species are restricted to, what to do and whom to call if a specimen is found outside the listed area, and practices for reducing the transport of ANS between bodies of water. Other contributions from the Sea Grant Program include Traveling Trunks, distribution of MN DNR produced field guides on ANS, and training packages providing details of individual ANS. A Three State Exotic Species Boater Survey, conducted in part by funding from the National Sea Grant College, found that Minnesota put forth a high level of effort and used a variety of methods in getting out the message about ANS in an attempt to evaluate the effectiveness of change in boater behavior. Examples of such efforts in Minnesota include civil penalties for transporting ANS, road checks for the enforcement of regulations, and inspection/education programs at boat accesses to infested waters. Additionally, ANS messages have been presented on billboards, the cover of the fishing regulations pamphlet, via the media, at conferences/workshops and boat/sports shows, in fact sheets and brochures, and in educational packages distributed to lake and fishing associations.

Other programs in the Great Lakes area directed at educating the public about nonindigenous species include:

- National Aquatic Nuisance Species Clearinghouse
- The Sea Grant Nonindigenous Species Site (SGNIS)
- The National Zebra Mussel Training Initiative
- Great Lakes Sea Grant Network
- Exotic Aquatics and Zebra Mussel Mania Traveling Trunk Program
- Citizen Monitoring Program
- Purple Loosestrife Biocontrol Project
- Exotic Species Day Camp for Educators

10.6 DETECTION AND MONITORING EFFORTS

Detection and monitoring is also an important component of an ANS program. There are two goals in a successful monitoring and detection program. The first goal is to engage in early detection of new invaders poised to enter the Great Lake ecosystem since the best chance to control the spread of the species is at its first introduction. Second, continuous monitoring and surveillance of already existing ANS is needed to track their spread throughout the basin. Currently, the USFWS maintains a surveillance program for monitoring the spread of ruffe and round goby. GIS technology is used to track up to hundreds of ANS and their movement in the Great Lakes. An important part of this program is public education. All new reports of dozens of ANS are maintained in a national database by the U.S. Geological Survey's Florida Caribbean Science Center in Gainesville, Florida. The Michigan Department of Natural Resources monitors Lake Huron fish stocks through two Great Lakes Research Stations on Lake Huron. At these stations, measured changes in fish stocks due to harmful invaders and other external sources are monitored, especially the progress of sea lamprey control assessed using lake trout wounding rates and recovery of lake trout stocks.

There is currently a ruffe monitoring program in Lake Superior. The USFWS Lake Superior Biological Station has had ruffe populations and those of associated fish communities under surveillance since 1992. Under this program, likely locations of ruffe populations are surveyed and the range of ruffe is then monitored and the status of peripheral populations is investigated. The Lake Superior Biological Station is also monitoring ruffe populations in the St. Louis River.

Further monitoring efforts need to be created or expanded to help reduce the threat of future infestations by nonindigenous species.

10.7 PREVENTION ACTIVITIES

Once ANS has established a population, or naturalized, it is unlikely they can be eliminated. With a few exceptions (e.g., sea lamprey) non-native aquatic species **cannot** be controlled, except in confined areas, once they are established. By the time a non-native species is noticed it is usually well-established, and unless its distribution is constrained by very specific habitat requirements, it will become ubiquitous and uncontrollable. Hence, a major emphasis must be placed on prevention, and not solely on control, which is usually not a realistic option.

Ballast Water Management

The primary focus of prevention efforts has been ballast water management, including a national ballast management program under NISA of 1996. The issue of ballast water in preventing the introduction of nonindigenous species into the Great Lakes ecosystem is discussed in detail below.

All cargo ships contain huge ballast tanks. These tanks are filled in port to help steady ships as they travel, and are emptied once cargo is loaded. Each tank can hold millions of gallons of water, which can contain any and all of the aquatic life found in port waters and sediments; everything from bacteria and algae to worms and fish has been found in ballast water. All ships traveling into the Great Lakes are required to exchange ballast water in the open ocean prior to entry. However, despite the mandatory emptying of ballast tanks, organisms may establish permanent or semi-permanent communities in the layer of water and sediment that often remains at the bottom of the tanks. In these situations, adult organisms may reproduce and release larvae into ballast water, for eventual release in port, while adults remain in the sediment to reproduce further. In order to stop these harmful discharges, ships must takes steps to avoid taking organisms into ballast tanks, to kill organisms during the voyage, or to avoid discharging organisms when ballast water is released (MIT 1999). To test for compliance with ballast water exchange requirements, the Coast Guard has the authority to board all ships entering the Great Lakes and randomly sample ballast water for salinity, which is subsequently compared with the salinity standard. The Coast Guard recognizes that salinity cannot be the only method of verification of open ocean exchange at a coastal port.

Alternatives to ballast exchange as a means of control of organisms inhabiting ballast water include filtration, ultraviolet light, acoustics, salinity, heat, chemical biocides, sedimentation, pH treatment, oxygen deprivation, and discharge to reception vessels (Reeves 1996). Despite the available prevention technologies, it is unlikely that such solutions will be implemented by the shipping industry without incentives or regulations. The Canadian Coast Guard has expressed a need for biological standards for ballast tanks. Without such a restriction, the Canadian Coast Guard does not foresee voluntary implementation of new technologies for ballast water treatment. This is a forward looking initiative that will require participation of both the shipping industry and the ballast water management programs.

NISA Section 151.2035(b)(2) states that retaining ballast water on board is an option, and Section 151.2035(b)(4) states that discharging ballast water to an approved reception facility is another option. In order for the Coast Guard to approve a method alternative to ballast exchange, they must consider whether the method conforms to existing laws and standards, how effective the method is in reducing the viability of organisms within the vessel's ballast water, and how the vessel operator will verify that the system is operating as designed (U.S. Coast Guard 1999)

There are penalties for failing to comply with the Great Lakes ballast water provisions of NISA that include restriction of operation, revocation of Customs clearance, and possible civil and criminal penalties.

The NOBOB Issue

While adequate under many circumstances, ballast exchange poses safety, effectiveness, and accountability concerns that limit its scope and usefulness. The practice has particularly limited utility in the Great Lakes where most transoceanic vessels enter the system fully loaded with cargo and report NOBOB. They nonetheless transport organisms into the Great Lakes system in the residual water and sediment in the "empty" ballast tanks. A tool box full of alternative prevention technologies and practices is needed to address the range of vessel types and voyage patterns of today's waterborne transportation. In the long term, these tools may be solutions such as a combination of microfiltration and ultraviolet light treatments, which can be installed or designed into vessels. Technologies such as these could reliably resolve problems associated with fully-loaded vessels (NOBOB vessels) (Cangelosi 1997).

In an interim rule on implementation of the NISA Act of 1996 which became effective July 1, 1999, the Coast Guard presented its position on NOBOB vessels. “A vessel with NOBOB may not have a large quantity of ballast water on board, but the vessel does retain sediment and residual ballast water. The Coast Guard requests in this regulation that all vessels remove sediments in an appropriate manner on a regular basis. We are working on identifying possible management methods to reduce the threat of a vessel operator claiming NOBOB. However, it would be premature to issue regulations specifically for these vessels at this time. To ask a vessel operator in a NOBOB status to conduct a ballast water exchange could destabilize a vessel, causing it to submerge its load line or compromise seaworthiness by exceeding hull girder stress limits, or increase the stresses on the hull to the point they fracture.” (USCG 1999)

Other Prevention Programs

Another prevention program in the Great Lakes includes a proposal for setting up a quick response team that could be dispatched to an area where a newly introduced species has been reported to try to prevent the spread of the species beyond the introduction point. At this point in time, planning of such a team has not moved beyond the discussion stage but is still viewed as an option for future consideration.

Control Activities

Experts disagree about the relative importance of prevention and control. Effective control in aquatic systems is often impossible, but the impacts of ANS merit an attempt. Everyone agrees prevention is best, but it is difficult to measure success in prevention activities. Control activities need to be established and implemented to try to reduce the negative ecological and economic impact of nonindigenous species that have already been introduced into the Great Lakes ecosystem. At least partial success has been achieved in control programs with the sea lamprey, ruffe, and purple loosestrife.

ANS can be controlled by several general methods, including chemical, biological, mechanical or physical, and habitat management practices. While each of these methods may provide effective control, each has disadvantages as well. The use of chemicals raises concerns about environmental safety and long-term impacts. Identification and screening of biological control agents invariably takes many years, and improperly screened biological control agents have themselves become nuisance species in the past. Mechanical or physical controls are often very expensive. No single method is likely to provide the necessary control of nonindigenous species. Hence, a comprehensive control strategy involving a combination of techniques is often necessary for an effective control program.

Various control mechanisms are currently being implemented in the Great Lakes. To help control the expansion of the goby into other waterways, river barrier systems are being implemented, along with public education programs. Unfortunately, no effective measures have been found to date to decrease established populations of gobies. The ruffe is the subject of the first control program developed under the NANPCA. The control program was implemented in 1992 and has successfully delayed the spread of ruffe through the Great Lake and inland waters. This success was obtained largely through the campaign to limit the transport of ruffe, both intentionally and unintentionally, between bodies of water, particularly by controlling the transport of ruffe in ballast water carried out of Lake Superior. The control of ruffe has been given a great amount of attention because if they do spread, ruffe will pose a threat to fisheries and aquatic ecosystems throughout much of eastern North America.

The sea lamprey has cost millions of dollars in losses to fisheries and in costs of control, in addition to the depletion or extirpation of lake trout stocks. In 1956, a joint program between the United States and Canadian governments was implemented to address the harmful impacts of the sea lamprey. The Great Lakes Fishery Commission (GLFC) was created by the *Convention on Great Lakes Fisheries* between the United States and Canada in 1955, and control of sea lampreys within the Great Lakes basin was one of the Commission's principal responsibilities. The GLFC implemented sea lamprey control on the basis of an agreement between the U.S. and Canada reached at the Convention. The result was the development and application of an environmentally acceptable lampricide for use in controlling lamprey populations. Other mechanisms of control being used include mechanical and electrical barriers, and the experimental sterile-male-release-technique. These methods have achieved considerable success in controlling sea lamprey populations in the Great Lakes. Populations of sea lampreys in Lake Superior have been reduced to 10 percent of their former abundance, and the lake trout, their major prey, have recovered to self-sustaining populations in several areas. In other areas, lamprey predation continues to limit recovery of the lake trout.

While current activities have been moderately successful at preventing and controlling the effects of ANS, continued regulatory efforts and education programs are needed to help reduce the threat posed by these species in the Great Lakes.

10.8 RECOMMENDATIONS AND NEEDED ACTIONS

1. Engage in forecasting in an attempt to determine those species with exceptionally high invasion and impact potential, as suggested by Ricciardi and Rasmussen (1998) in a paper entitled, "Predicting the identity and impact of future biological invaders: a priority for aquatic resource management", so that proper steps can be taken to halt the spread of such species before they become a threat.

2. Take additional steps to maximize the effective functioning of programs already in effect for the prevention and control of ANS. Suggested steps include:

    - Develop a detailed database of all ANS, including biological information, behavior, previous ecological impacts and any other information that might prove useful in understanding and stopping current and future invaders. This inventory could take the shape of an online information clearing house, including an online GIS with distribution data, data submission, and management activities.

    - Clarify the roles of the various responsible agencies with regard to the issue of ANS, including the role of the Great Lakes states in helping to prevent and control nuisance species. While a high level of national involvement is necessary, state action and participation will ensure that regional and local concerns are also being addressed.

    - Implement a system to ensure that duplication of effort is kept to a minimum, in order to optimize the use of the resources the agencies have available to them.

    - Encourage interjurisdictional cooperation and information sharing, not just clarification of roles and avoiding duplication. Foster partnerships with industry and stakeholder interests and raising and/or maintaining awareness at all levels.

    - Develop and incorporate short-term management practices applicable to fully-loaded vessels in Coast Guard ballast management regulations for the Great Lakes (Cangelosi 1997).

3. Management agencies are hampered by a lack of technology to control ANS once they have become established. Research and development leading to new analytical and management tools are desperately needed for an adequate response to ANS (Busiahn 1993). The following strategies could be pursued to counter the impacts of ANS:

    - Baseline data on fish communities could be collected to detect changes brought about by introduced species.

    - Surveillance sampling could be conducted in likely locations to detect new colonizations.

- Information and education programs could be developed and promoted, so that the public understands the threat of ANS, does not transport them, and reports suspected new occurrences.

- Transport and possession of ANS by the public or the live bait industry could be regulated or prohibited.

- Fishery management agencies could develop working relationships with the maritime and bait industries, the U.S. and Canadian Coast Guard, the U.S. Army Corps of Engineers, and other non-traditional partners in the effort to prevent the introduction and spread of ANS. The Great Lakes Panel on Aquatic Nuisance Species provides an established coordination mechanism.

- Fishery management agencies could promote greater resilience in aquatic communities by restoring and protecting habitat, and through careful deliberation of stocking and harvest regulation. Results of management actions could be measured by long-term monitoring programs.

4. Develop priorities for dealing with ballast water issues. Examples include:

   - Develop clear and concise standards for ballast tanks and discharge of ballast water.

   - Focus on "best practical technology" for ballast water control.

   - Devise a short-term plan for dealing with the NOBOB issue.

   - Require that newly built ships incorporate technology to deal with the ballast water problem.

   - Ensure that both the U.S. and Canada are working together on ballast water management, regulation, and enforcement to ensure effectiveness of any established programs.

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ADDENDUM 10-A
DOCUMENTED EXOTIC AQUATIC SPECIES IN LAKE SUPERIOR

Species Name	Year of Introduction	First Location	Intentional or Unintentional
Fish:			
Alewife (*Alosa pseudoharengus*)	<1953	NA	Unintentional
American eel (*Anguilla rostrata*)	1970	Brule River	Unintentional
Atlantic salmon (*Salmo salar*)	1972	WI waters	Intentional
Brown trout (*Salmo trutta*)	1883	MI waters	Intentional
Chinook salmon (*Onchorhynchus tshawytscha*)	1967	MI waters	Intentional
Coho salmon (*Oncorhynchus kisutch*)	1966	MI waters	Intentional
Common carp (*Cyprinus carpio*)	1891	WI waters	Unintentional
Eurasian ruffe (*Gymnocephalus cernuus*)	1986	St. Louis River	Unintentional
Fourspine stickleback (*Apeltes quadracus*)[a]	1986	Thunder Bay	Unintentional
Pink salmon (*Onchorhynchus gorbuscha*)	1956	Thunder Bay	Unintentional[b]
Rainbow smelt (*Osmerus mordax*)	1930	Whitefish Bay	Unintentional[b]
Rainbow trout (*Salmo gairdneri*)	1883	Lake Superior	Intentional
Round goby (*Neogobius melanostomus*)	1995	Duluth Harbor	Unintentional
Sea lamprey (*Petromyzon marinus*)	1938	Two Harbors	Unintentional
Threespine stickleback (*Gasterosteus aculeatus*)[a]	1994	Taconite Harbor	Unintentional
White perch (*Morone americana*)	1986	Duluth Harbor	Unintentional
Aquatic Invertebrates:			
Aquatic oligochaete (*Ripistes parasita*)	1987	S. Lake Superior	Unintentional
Asiatic clam (*Corbicula fluminea*)	1999	Duluth Harbor	Unintentional
Rusty crayfish (*Orconectes rusticus*)[a]	1999	St. Louis River	Unintentional
Spiny waterflea (*Bythotrephes cederstroemi*)	1987	E. Lake Superior	Unintentional
Zebra mussel (*Dreissena polymorpha*)	1989	Duluth Harbor	Unintentional
Diseases and Parasites:			
Furunculosis (*Aeromonas salmonicida*)	NA	NA	Unintentional
Microsporidian parasite (*Glugea hertwigi*)[c]	1930s	Wide distribution	Unintentional
Bacteria kidney disease (*Corynebacterium* ssp.)[a]	NA	NA	Unintentional
Whirling disease (*Myxobolus cerebralis*)	NA	NA	Unintentional
Wetland and Aquatic Plants:			
Bur reed (*Sparganium glomeratum*)	1936	Lake Superior	Unknown
Bittersweet nightshade (*Solanum dulcamara*)	<1843	Lake Superior	Intentional
Curlyleaf pondweed (*Potamogeton crispus*)	<1993	Lake Superior	Intentional
Eurasian watermilfoil (*Myriophyllum spicatum*)[a]	<1996	Bayfield	Unintentional
Purple loosestrife (*Lythrum salicaria*)	1907	Duluth	Intentional
Yard dock (*Rumex longifolius*)	1901	Isle Royal	Unintentional[d]

NA - Information not available
[a] Data yet to be confirmed
[b] Inadvertent introduction or spread resulting from intentional introduction elsewhere
[c] Spread with rainbow smelt introduction
[d] Inadvertent spread from cultivation