Briefing Paper: Great Lakes Nonindigenous Invasive Species

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Preface

This briefing paper is presented to the U.S. Environmental Protection Agency (U.S. EPA), Great Lakes National Program Office (GLNPO) as an informational resource in the development of regional policy on the prevention and control of Great Lakes nonindigenous invasive species (NIS). The document was initially prepared for stakeholders participating in the regional workshop *Great Lakes Nonindigenous Invasive Species*, hosted by the U.S. EPA-GLNPO , U.S. EPA-Office of Research and Development and the Great Lakes Commission in Chicago, Ill. in October 1999. The workshop, one of four regional workshops held across the country, was held to elicit ideas on how the U.S. EPA might participate more strongly in a federal initiative against noxious and nonindigenous species.

The workshop was held in support of an executive order on invasive species (1999) that established a cabinet-level executive council to oversee an interagency program to prevent, detect, monitor and control nonindigenous invasive species and to restore native species and habitats. The Great Lakes workshop invited specialists to discuss the ecological and economic effects of aquatic and terrestrial invasive species on the Great Lakes basin as well as potential solutions to NIS problems. The threat of nonindigenous invasive species is particularly serious in the Great Lakes and efforts to prevent and control the introduction and spread of these species can serve as useful examples throughout the binational Great Lakes basin and beyond. The information gathered at the workshop has been incorporated as part of the document that follows. The conduct of the workshop and the associated briefing paper were made possible by a grant from the U.S. EPA-GLNPO.

The briefing paper was prepared by the staff of the Great Lakes Commission's Resource Management and Environmental Quality Program: Katherine Glassner-Shwayder (project manager, principal author), Thomas Crane (program manager), Marcia Woodburn (research associate), Elizabeth Repko (research associate), Chase Huntley (editor), Lisa Koch (editor) and Courtney Shosh (editor). Members of the Great Lakes Panel on Aquatic Nuisance Species and other regional stakeholders participating in the workshop provided guidance, review and technical assistance. Their contributions were critical to the success of the project.

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Introduction

Invasion by nonindigenous (non-native) species is one of the most challenging environmental issues facing natural resource managers and environmental policy makers today. Nonindigenous invasive species (NIS), which have been labeled invasive species, exotics, aliens and a number of other names, all share the common characteristic of "introduction into an environment in which they did not evolve and thus usually have no natural enemies to limit their reproduction and spread" (Westbrooks 1998). In their native habitat, where they have genetically and ecologically evolved, these organisms may not be a high risk proposition. However, when aquatic and terrestrial species are transported to ecosystems outside their established range, problems can be caused for native organisms, disturbing the balance of natural ecosystems by altering population, community, and ecosystem structure and function.

Since the early days of European colonization, more than 6,500 species of established, self-sustaining populations of nonindigenous species have been introduced into the United States (Office of Technology Assessment 1993, U.S. Geological Survey, Gainsville, Fla., unpublished plant and fish data). They represent all phyla, from microorganisms to various plants and animals, both terrestrial and aquatic. Some of these species have been intentionally introduced beyond their native range for beneficial uses, such as aquaculture, aquarium and horticultural practices, or biological controls. A number of intentional introductions have escaped into the wild and become established as reproducing populations, resulting in unexpected, yet significant ecological and economic impacts. The common carp is an example of a nonindigenous species that has been intentionally introduced, causing extensive ecological and economic damage resulting from its impact on the native fishery in this country. Other nonindigenous species have become established through unintentional introductions. These species were unknowingly transported beyond their native range in the course of some unrelated activity, such as ballast water transport for transoceanic shipping. The classic example of an unintentional introduction is the zebra mussel *(Dreissena polymorpha*), the infamous mollusk that has colonized hard surfaces throughout the Great Lakes, damaging the natural ecosystem and human infrastructure in the basin and beyond.

Both intentional and unintentional introductions of nonindigenous species and their ensuing spread have caused significant ecological and economic impacts affecting the use of the resource as well as posing risks to human health. On a global scale, evidence suggests these ecological changes are escalating to threaten the biological diversity and ecological integrity of the aquatic and terrestrial habitats around the world (Bright 1998). Although often slow to surface, these pervasive, insidious and, for all practical purposes, irreversible changes stress the health of invaded ecosystems.

As invasions of nonindigenous species continue on a global scale, the distinctiveness of the Earth's biota, evolving since isolation of the continents occurred over180 million years, has become more homogenized as many populations of native species have declined or disappeared altogether. This form of biological pollution, which can rapidly multiply when established, is considered to have greater impacts on global environmental health than many chemical types of pollution, which have been found to degrade over time (Westbrooks 1998). Biological invasions all too frequently take on a life of their own. Once introduced into a non-native habitat, the nonindigenous species establish themselves, reproduce and spread from one ecosystem to the next, often wreaking havoc along the way. Although progress has been made to remediate the ecological damages caused by chemical pollutants and contaminants, "little attention has been paid – and almost no progress has been made" to address the problems caused by the introduction and spread of nonindigenous species (U.S. Geological Survey 1998).

Nonindigenous Species Invasions in the Great Lakes Basin: A Growing Problem

Aquatic Invasions

The Great Lakes and their connecting channels and rivers form the largest surface freshwater system in the world. Water-related resources are an integral part of activities such as recreation and tourism, valued at $15 billion annually, $6.89 billion of which is related to the fishing industry. Approximately 75,000 jobs are supported by sport fisheries, and commercial fisheries provide an additional 9,000 jobs (Great Lakes Fishery Resource Restoration Study 1994). This valuable water resource is threatened by the infestation of harmful nonindigenous aquatic nuisance species (ANS), which alter the number and distribution of native species and have broad economic and societal impacts extending far beyond the shoreline of residents and recreational users.

The Great Lakes ecosystem has been subject to ANS invasions since the settlement of the region by Europeans. Since the 1800s, at least 146 known nonindigenous aquatic organisms established themselves in the Great Lakes. Based on the 1993 publication of Mills, et al., 139 of these species are listed in Appendix A. The estimated current rate of invasion is one new organism annually (Bright 1998). The bulk of these organisms are plants (59), fish (25), algae (24), mollusks (14) and oligochaetes (7). About 55 percent of these species are native to Eurasia; and 13 percent are native to the Atlantic Coast (Mills et al. 1993, Mills et al. 1998). Since 1993, at least seven additional nonindigenous aquatic species have been introduced, including: European amphipod (*Echinogammarus ishmus*), blueback herring (*Alosa aestivalis*), fishhook flea *(Cercopagis pengoi*), New Zealand mud snail *(Potamopyrgus antipodarum)*, round goby (*Neogobious melanstoma)*, tubenose goby *(Proterorhinus marmoratus)*, and *Thalassiosira baltica* (a diatom) (Mills pers. comm. June 2000).

The question has been posed: Why have so many species successfully invaded the Great Lakes ecosystem? A fundamental reason for this phenomenon is that the Great Lakes were isolated from many source populations during the last major glaciation about 10,000 years ago. As a result, the Great Lakes ecosystem, on a relative scale, did not evolve a diverse set of native aquatic species. This condition has been conducive for the establishment of nonindigenous species upon their introduction (Dettmers 1998).

As human activity increased with the progression of European settlement in the Great Lakes watershed, so too has the rate of introduction of nonindigenous aquatic species. The canal systems built within the Great Lakes removed physical barriers and opened the doors for nonindigenous species, linking the lakes with both the Atlantic and Mississippi drainages (Mills 1993, Dettmers 1998). Other human disturbances also created stressful conditions for native populations, thus giving a competitive edge to invading species (see Figure 1).

The single largest source of unintentional introductions has resulted from maritime commerce, with ANS transport occurring via ocean vessels originating in foreign ports. Some species attached themselves to the hulls of ships, while others were carried in ballast water taken on by ships in foreign ports for stability. It is standard operating procedure for ships embarking from ports around the world to take on large quantities of coastal water (often millions of gallons) to lower the vessel to a safer and more efficient position in the water. Ships that have taken on ballast are considered “biological islands” as they make their journey because of the wide variety of organisms carried in the water in their ballast tanks.

Figure 1. Factors Facilitating the Spread of Aquatic Invasive Species

Human activities can unknowingly stress native species and give invaders an advantage. These activities include:

- clear cutting and farming practices that increase sedimentation and water turbidity
- industrial pollution
- urbanization
- intensive commercial fishing

Source: Dettmers 1998

These organisms include, among others, pathogens, plants, zooplankton, mollusks and fish that may remain suspended in the water column of ballast or sink down into the sediment on the bottom of the tank. When ships reach their destinations, often halfway across the world from their point of origin, these nonindigenous species are released when ballast water is discharged. Some of the most harmful biological invaders transported via shipping include the sea lamprey (*Petromyzon marinus)*, zebra mussel, ruffe *(Gymnocephalus cernuus)*, round goby (*neogobius melanstomus*) and spiny waterflea *(Bythrotrephes cederstroemi)*.

Ballast water began to be commonly used in ships with the introduction of steel construction in the mid-1800s. As world trade has intensified since that time, the threat of transport of nonindigenous species has grown. Since the opening of the St. Lawrence Seaway in 1959, there has been a dramatic surge in introductions, with an estimated 60 percent attributable to transoceanic ballast water (Mills et al. 1993). Over the past century, more species have been able to survive the journey and thrive in new waters due to decreased shipping time with faster vessels and, ironically, improved water quality in Great Lakes harbors with the advent of pollution controls. As the expansion of international trade continues, new ANS introductions are likely to occur from waters around the globe.

ANS introductions and dispersal in North American waters also result from activities that provide economic benefits, such as the aquaculture industry, aquarium trade, recreational boating, sport fish stocking, bait business and horticultural practices. Animal and plant species, e.g., the common carp *(Cyprinus carpio)*, Eurasian watermilfoil *(Myriophyllum spicatum)*, water hyacinth *(Eichhornia crassipes)* and rusty crayfish *(Orconectes rusticus)* have been introduced and dispersed from these types of activities and have caused unexpected ecological and economic impacts. Sport fish, such as salmon and trout (coho, *Oncorhynchus kisutch*; chinook, *Onchorhynchus tshawytscha*; rainbow or steelhead, *Oncorhynchus mykiss*) that are not native to the lakes were originally introduced to control alewives *(Alosa pseudoharengus),* which entered the Great Lakes after the Welland Canal was completed in 1829. Upon their intentional introduction, these salmonid fish have become a valued catch and are now artificially propagated in hatcheries to support a multibillion dollar recreational and commercial fishery. Game and fish agencies, which have traditionally been major importers of nonindigenous species, are in the process of recognizing the need for more regulation to prevent future NIS introductions into the Great Lakes region. Unfortunately, however, there are so many introduced species in the Great Lakes that some biologists argue that it is now a “man-made aquaculture system” (Dettmers 1998).

Once introduced into the Great Lakes, many nonindigenous aquatic nuisance species have spread to inland lakes, rivers, wetlands and waterways, thus adding another dimension to the ANS problem. Inland transport frequently occurs by way of barges, recreational watercraft, bait buckets, fish stocking and other human-assisted transport mechanisms. For example, the zebra mussel has spread from the Great Lakes by way of barge traffic and recreational boating, infesting many inland freshwater ecosystems. In a neighboring watershed, the upper Mississippi, the zebra mussel has degraded an economically valuable commercial mollusk fishery (Great Lakes Panel 1998).

Approximately 10 percent of nonindigenous aquatic species introduced into the Great Lakes have had significant impacts, both economic and ecological. The remaining 90 percent have potentially harmful impacts but are insufficiently researched and understood. The impacts of certain species, such as the zebra mussel, have been enormous resulting in costly procedures to remove colonies from intake pipes and related infrastructure. The invasion of the sea lamprey, a parasite that attaches to large fishes with a sucker mouth armed with teeth that consume flesh and fluid from its prey, has resulted in substantial economic losses to recreational and commercial fisheries. Protection of the Great Lakes fishery (both native and nonindigenous species) from sea lamprey predation has required annual expenditures of millions of dollars to finance chemical control programs (Great Lakes Panel 1996(a).

Alewife, introduced through the canal systems built in the Great Lakes, littered beaches each spring and altered food webs, causing increased water turbidity. These impacts subsided with the intentional introduction of salmonids that were stocked as predators to keep alewife populations under control. The ruffe, a small percid fish, became the most abundant fish species in Lake Superior's St. Louis River within five years of its detection in 1986. Its range, which has expanded to Lake Huron, poses a significant threat to the lower lake fishery. Five years after first being observed in the St. Clair River, the round goby can now be found in all of the Great Lakes. The goby is considered undesirable for several reasons. It preys upon bottom-feeding fishes, overruns optimal habitat, spawns multiple times a season, and can survive poor water quality conditions (Great Lakes Panel 1996(a)).

Another nonindigenous aquatic species, the spiny water flea, a tiny crustacean with a sharply barbed tail spine, was most likely introduced through ballast water. The northern European native was first found in Lake Huron in 1984. Although researchers do not know what effect the invader will have on the ecosystem, resource managers suspect that the water flea competes directly for food with small fish such as perch. The spiny water flea is now found throughout the Great Lakes and in some inland lakes.

As mentioned above, the zebra mussel, another ballast water introduction, has caused serious economic and ecosystem impacts as well. In the absence of controls, it is expected that zebra mussel fouling will inflict an economic toll estimated at $5 billion over the next ten years. Municipal treatment and power plants, commercial and recreational vessels, and beach areas are all vulnerable to the negative impacts of the zebra mussel. The cost to large water users in the Great Lakes, alone, totals an average of $360,000 per year. From 1989-1994, documented cumulative costs associated with the zebra mussel for users were $120 million (Hushak 1996). The consequences of zebra mussel infestations are not confined to economic burdens. Preliminary research and supporting observations have indicated that the impact of the zebra mussel on the native ecosystem could be significant because of their ability to limit food availability, decrease spawning areas and harm fishery ecosystems.

Nonindigenous plants also have been introduced to the Great Lakes basin. Purple loosestrife *(Lythrum salicaria)*, a wetland plant from Europe and Asia, was first introduced to the east coast in North America. It invades marshes and lakeshores, replacing cattails and other wetland plants. Purple loosestrife is unsuitable as cover, food or nesting sites for a wide range of native wetland animals including ducks, geese, rails, bitterns, muskrats, frogs, toads and turtles. Eurasian watermilfoil, introduced to North America from Europe, has spread westward into inland lakes primarily by boats and waterfowl. In shallow areas, the plant can interfere with water recreation such as boating, fishing and swimming. The plant's floating canopy can also crowd out important native water plants.

The results from research conducted in the past decade indicate that ANS invasions in the Great Lakes are causing significant ecological and economic impacts in the region and beyond. The risks posed by nonindigenous species will only escalate as invasions continue into the future. It is critical to support continued research aimed at documenting the wide array of ANS impacts, as well as to find ways to prevent additional ANS introductions, control aquatic invaders already established and prevent their spread. The ultimate goal of ANS research should be directed towards management action facilitating the prevention and control of nonindigenous aquatic species. The uncertainties and risks associated with prevention and control programs also must be considered when working towards ameliorating problems. The following examples illustrate some of these risks: safety hazards posed by ballast exchange to the ship and crew in efforts to minimize new ANS introductions through transoceanic shipping, health risks posed to other native species with the application of chemicals to control aquatic invaders and the potential for new biological and ecological problems to evolve when a nonindigenous species is introduced to control other introduced species (e.g., the introduction of chinook salmon to control alewives has also introduced bacterial kidney disease to some native salmonid populations).

Terrestrial Invasions

Invasive plants inhabiting terrestrial ecosystems comprise another subset of nonindigenous species that cause billions of dollars in damages annually to agricultural, recreational and tourist industries in the United States. As is the case with other nonindigenous species, invasive plants have been introduced into an environment in which they did not evolve, and, therefore, their populations are not kept in check by natural enemies. High reproductive rates and fast growth, among others characteristics (see Figure 2), facilitate the invasion of new habitats and the ability to outcompete native plants for light, water and nutrients.

Figure 2. Characteristics of Successful Invaders

- early maturation
- profuse reproduction by seeds and/or vegetative structures;
- long life in the soil
- seed dormancy that ensures periodic germination and prevents seedlings from sprouting during unfavorable conditions
- adaptions for spread with crop seeds by natural agents and by humans
- production of biological toxins that suppress the growth of other plants
- prickles, spines or thorns that can cause physical injury and repel animals
- the ability to parasitize other plants
- seeds that are the same size and shape as crop seeds which are labor-intensive to separate
- roots or rhizomes with large food reserves
- survival and seed production under adverse environmental conditions
- high photosynthetic rates

Source: Westbrooks 1998.

Agricultural and horticultural cultivation of nonindigenous plants is a primary mechanism responsible for their introduction and spread in the United States. The historical roots of these practices date back to the early years of European colonization when many species of European plants were introduced as crops and for ornamental purposes. It has been said that the use of European plant species assuaged "a kind of colonial angst" stemming from "the anxiety of difference." While many of these nonindigenous plant species benefit society (for example, corn, rice, wheat, and soybeans), a number of the plants introduced have become invasive. In the case of horticulture, practices such as gardening and landscaping are considered "a gargantuan engine of biotic mixing that has helped unleash some of the world's worst plant invasions." In the continental United States and Canada, garden introductions are estimated to account for about half of the 300 serious pest plants of natural areas. To add insult to injury, species that are proven hazards, such as purple loosestrife, generally remain in trade. In fact, more than 60 percent of the worst weeds that have invaded North America's natural areas are still being sold by nurseries (Bright 1998).

Although a nonindigenous plant may appear harmless upon introduction, these plants adapt and explode in their new environment in the absence of co-evolved predators. By the time an invasive species is recognized as a problem, it has become well established and difficult or impossible to eliminate (Westbrooks 1998). The problems caused by invasive plants have increased dramatically over the past decades, due, in part, to increasing population growth and associated development trends, such as an increased demand for food and fiber, overuse of public land for recreation and commercial production, increased international travel, and globalization of world trade. These activities all facilitate the introduction, establishment and spread of invasive plants.

The primary problem caused by invasive plants in terrestrial habitats is the disruption of food and fiber production for humans. On a global scale, weed infestation in 1975 was estimated to have reduced global crop production by an estimated 11.5 percent. In the United States during the 1980s, $3 billion was spent annually for chemical weed control and about $2.6 billion for cultural, ecological and biological controls. At that time, about 17 percent of crop value was being lost due to weed interference and money spent on weed control (Westbrooks 1998).

In 1994, economic impacts of weeds on the U.S. economy were estimated to be $20 billion or more annually. In the agricultural sector, losses and control costs associated with weeds in 46 major crops, pasture, hay and range, and animal health were estimated to be more than $15 billion per year. Losses and control costs totaled about $5 billion per year in non-crop sectors including golf, turf and ornamentals, highway rights of way, industrial sites, aquatic sites, forestry and other sites. (Westbrooks 1998).

The introduction of European plants since the colonial era has had irreversible impacts on croplands in the United States. Invasive plants, frequently referred to as noxious weeds, impact agriculture in a variety of ways (see Figure 3). Large-scale farming, where a monocultural approach to agricultural production pervades, is particularly vulnerable to the introduction of terrestrial nonindigenous plants as well as animals (e.g., insects). "In any kind of ecosystem, natural or artificial, the closer you get to a monoculture, a system dominated by a single species or variety, the less stable the system is likely to be. Any pest that succeeds in attacking the dominant organism stands a good chance of overrunning the entire terrain" (Bright 1998).

Figure 3. Impacts of Noxious Weeds on Agriculture

- function as superior competitors
- limit the choices of crop rotation sequences and cultural practices
- cause loss of crop quality
- act as vectors of other pests, such as plant pathogens, nematodes and insects
- interfere with crop harvesting
- necessitate extra cleaning and processing procedures
- require expenditures of billions of dollars on pesticides
- interfere with water management in irrigated crops
- increase transportation costs
- reduce land values due to the loss of productive potential on weed dominated land and reconized costs required to restore to full productivity; and
- lead to the evolution of herbicide resistant populations

Source: Westbrooks 1998.

The terrestrial invasion of nonindigenous plants also threatens the biodiversity, quality and ecosystem functions of natural habitats. Invasive plants constantly encroach into parks, preserves, wildlife refuges and urban green spaces where they compete with native species for dominance and disrupt the natural landscape. In the case of horticulture, introduced ornamentals that are used in the yard and gardens are generally poorly adapted for survival without human care. However, some of these imported species that have escaped from their intended areas of residency have proven to be very aggressive with native plants (see Figure 4).

Figure 4. Ecological Impacts of Escaped Ornamentals

- displacement of native grasses increases surface water run-off and soil erosion
- reduction of the presence of important cryptogamic ground crust, composed of small lichens and mosses, that is important for soil stabilization, moisture retention and nitrogen fixation
- degradation of spawning habitat by causing soil erosion
- displacement of native species, particularly endangered species that are vulnerable to environmental changes caused by nonindigenous species
- degradation of wildlife habitat resulting from reduced population of native vegetation that provides shelter and food for native vertebrates and invertebrates
- reduction in wildlife resulting in decreased availability of winter forage

Source: Westbrooks 1998.

The cooperation of the horticultural industry is critical to advancing NIS prevention and control. To date, however, this industry has been known to oppose tight regulatory control of nonindigenous species. In some instances, plant importers recognize the irreversible dangers of nonindigenous plant introductions and, to some extent, support quarantine measures and “dirty lists” of species known to be invasive. There also is increased awareness among state departments of transportation, charged with landscaping highways to impede soil erosion, to replace the traditional use of nonindigenous plants for indigenous species. Unfortunately, however, many horticulturists, through trade associations and as individuals, attempt to influence the political process in establishing NIS regulatory measures (Mack et al. 2000).

The following list of nonindigenous plants provides a brief description of some of the worst invaders in the state of the Minnesota, which widely applies to the Great Lakes region. This information has been excerpted from the article "Weeds Gone Wild" by Jay Rendall as presented in the *Minnesota Volunteer* (1998), published by the Minnesota Department of Natural Resources:

- Exotic buckthorns *(Rhamnus cathartica and R. frangula)*: Mention buckthorn to folks with wooded land and you'll probably hear a story, reminiscent of a hillbilly feud, about their long-standing battle to keep it off their property. Exotic buckthorn has invaded plant communities from state parks to backyards. European or common buckthorn invades woodlands. Glossy or columnar alder-buckthorn is generally found on moist soils.
- Exotic honeysuckles *(Lonicera tatarica, L. morrowii, L. maackii, and the hybrid L. x bella)*: Exotic honeysuckles 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. Remove early invaders or they will soon dominate. Planting is discouraged.
- Garlic mustard *(Alliaria petiolata)*: Garlic mustard spreads and dominates the ground flora in forests, replacing native woodland plants. Seedlings of this biennial herb germinate in early spring and by mid-summer 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. Heavy infestations of garlic-mustard are in the Twin Cities area, especially Hennepin County, where the plant threatens native plants in shaded sites such as Wood-Rill Scientific and Natural Area. It is also invading maple-basswood forests in Chippewa National Forest. 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 *(Euphorbia esula)*: If you've ever pulled a dandelion and thought it had a long root, imagine trying to get rid of a plant that has roots that can extend 35 feet, grows through asphalt, and flings its seeds 15 feet. No kidding. It's leafy spurge, and it invades prairies, roadsides, and pastures. In places such as Lake Bronson State Park it outcompetes native grassland flora. 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 by the U.S. and Minnesota departments of agriculture.
- Spotted knapweed *(Centaurea maculosa or C. biebersteinii)*: Don't be fooled by the heatherlike appearance of this plant: It is not for gardens. Spotted knapweed 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 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.
- Reed canary grass *(Phalaris arundinacea)*: European and cultivated strains were

originally introduced as forage. This widely planted grass has also been used to establish cover on streambanks and wetland projects. Because native plant populations are excluded after this species invades, it is recommended to plant alternative native grasses and grasslike plants in conservation projects.

It is important to recognize the value of studying invasive plants, such as those listed above, to identify common characteristics that can be used to predict future invaders and develop effective management approaches. Biologically, many invasive plant species are found to be aggressive colonizers, especially in areas of disturbance. They are able to successfully out compete native plant species with rapid growth that is seasonally earlier and more dense than native vegetation. For instance, the competitive edge leans toward garlic mustard with its high rate of seed production and to reed canary grass with its ability to reproduce through extensive rhizomes that are difficult to control. Invasive plants may also have the ability to out compete native species with characteristics that deter the establishment of native species. Buckthorn, for example, exhibits an allelopathic quality, producing a substance into the soil which acts to inhibit the growth of surrounding vegetation. In terms of physical environment, invasive plants tolerate a wide variety of environmental conditions and have relatively few, if any, predators. They move into disturbed sites quickly and have a more difficult time establishing themselves in healthy ecosystems (refer to case studies section on invasive plants as found in this document).

As is the case with aquatic invaders, research should continue on invasive plants and the effects they incur on terrestrial ecosystems and the economic impacts resulting from these ecosystem changes. This recommendation has been expressed in the following quote from a 1998 report, *Status and Trends of the Nation's Biological Resources,* published by the U.S. Geological Survey: "Humans receive many free ecosystem services from nature, such as pollination of agricultural crops, development and protection of soils, oxygen production and purification of air, water filtration, coastal protection by wetlands, and production of food resources in estuaries. How these services have been affected by invasive nonindigenous species is largely undocumented, as is how the services will continue in the face of disruptions by invasive nonindigenous species." To develop sound policy on the prevention and control of terrestrial nonindigenous species, such as invasive plants, scientific data are needed on their biology, physiology, ecology and behavior. To support management action for effective prevention and control, information also is needed on the chronology of introduction, their pathways, and rates of modes and dispersal (U.S. Geological Survey 1998).

According to the Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW), research priorities on invasive plants should focus in the following areas: prevention, control and restoration (FICMNEW 1998). To be successful, this research will require a great deal of cooperation between state, federal and local governments; private industry; public and private land managers; and concerned individuals. For effective implementation, outreach and regulatory programs will need to be developed in a manner that applies across jurisdictional boundaries. A diverse source of funding will also be critical. Ultimately, political and public support will be vital to the development and implementation of prevention and control programs that are successful.

Assessing Overall Economic Impacts of Aquatic and Terrestrial Species on a National Scale

The economic impacts caused by nonindigenous species have proven difficult to determine. In most cases, impacts are assessed on a national scale, as will be presented in the following section. Species-specific costs resulting from NIS invasions in the Great Lakes region will be presented, when available, in the case studies section of this report.

The 1993 Office Technology Assessment (OTA) Report to Congress entitled *Harmful Nonindigenous Aquatic Nuisance Species in the United States* attempted an economic impact assessment based on a comprehensive survey of invasive plants, animals and microbes found to be living beyond their natural geographical range in the United States as established, self-sustaining populations. The economic assessment included more than 4,000 species of foreign origin: 2,000 plants, 2,000 insects, 142 terrestrial invertebrates, 91 mollusks, and 70 species of fish. The economic costs resulting from these nonindigenous species was estimated in the range of hundreds of millions to billions of dollars per year. Average costs reported in the OTA report were $1.1 billion per year for 79 species. The report did not detail precise estimates of the economic damage, or put a dollar value on the profound environmental damages ranging from ecological perturbations, and extinction of indigenous species to more subtle ecological changes resulting in loss of biodiversity. However, the report did raise the issue that cost assessments tend to underestimate losses caused by those nonindigenous species that are overlooked, and that intangible, nonmarket impacts, such as ecological damages, cannot be adequately assessed (OTA 1993).

A 1999 study from Cornell University counted more than 50,000 nonindigenous species in the United States causing economic costs of $138 billion annually (Pimental et al. 1999). Cost estimates included control, damage to property values, health costs and other factors (see Table 1). Reasons given for higher economic costs in this study as compared to the OTA report were based on damage assessments of more than 10 times the number of species with higher costs assessed for some of the same species. The Pimental report also qualified that the economic costs in the study would be several times higher than $138 billion per year if monetary values could be determined for species extinctions, losses in biodiversity, and other forms of ecological degradation and aesthetics.

Table 1. National Species-Specific Annual Costs of Three Aquatic Invaders

Species	Annual Cost	Expenditures
purple loosestrife	$45 million	control
zebra mussel	$310 million	cleaning water intake pipes, filtration equipment, power generating equipment, etc., but *not* damage to docks, recreational or commercial boats, or other problems
sea lamprey	$10-15 million	control

Source: Pimental et al. 1999

Another study conducted by New York Sea Grant and the national Aquatic Nuisance Species Clearinghouse quantifies the economic impact of zebra mussels throughout their North American range from 1989 through 1995 (O'Neill 1995). The types of facilities examined included golf courses, marinas, recreational facilities, institutions (hospitals, colleges, etc.), impoundments and reservoirs, fish hatcheries and aquaculture facilities, navigation locks, shipping and navigation, national scenic riverways, public agencies, industries, drinking water treatment facilities and electric power generation facilities.

Of the 436 facilities responding to the survey, 339 reported expenses related to zebra mussels (see Figure 5), for a total of $69.07 million. The maximum facility expenditure was $5.95 million; the mean expenditure was $206,000 per facility. The hardest hit sector was the electric generation industry for which the total economic impact was $35.3 million for 80 facilities. Nuclear power plants spent a total of $18.1 million, with a mean expenditure of $787,000 per facility. Other industries impacted were fish hatcheries and aquaculture related facilities ($88,000), navigation locks ($485,000), shipping and navigation ($563,000), and government agencies and authorities ($4.57 million for zebra mussel control research).

Figure 5. Categories of Zebra Mussel-Related Costs

- prevention efforts
- monitoring and inspection
- lost production and revenues
- planning, design, and engineering
- retrofit and/or reconstruction
- personnel training
- filtration or mechanical exclusion
- mechanical removal
- chemical treatments
- non-chemical treatments
- research and development
- Consumer education

Source: O'Neill 1995.

Economic impacts on agricultural production resulting from invasive plants are presented in the Terrestrial Invasions section of this report. Other significant costs to be considered are the millions of dollars spent annually, mostly by public agencies, to address the harmful effects from terrestrial invasions on natural ecosystems. Expenditures are required for the development and application of control and eradication measures, and for ecological restoration. For example, the removal of all damaging salt cedar (*Tamarix)* infestations bordering the lower Colorado River and restoration of indigenous vegetation would cost an estimated $45 million to $450 million (OTA 1993). Additionally, indirect economic effects result from reduced recreational opportunities in areas invaded by harmful plants and animals. The costs of backlogged control or eradication projects also should not be overlooked.

When assessing the economic impacts of nonindigenous species, it is important to recognize that while thousands of established aquatic and terrestrial invaders in the United States are not known to have caused ecological and economic damage, they should not be assumed to be harmless biota. On the contrary, these species should be viewed as "potential biological time bombs." A case in point is purple loosestrife, which existed in low numbers for more than a century before populations exploded, displacing valuable native wetland plants. Every year, more than 190,000 hectares of wetlands are taken over by this invasive nonindigenous plant. The nonindigenous plant existed at relatively low population levels or in geographically limited areas for decades before undergoing explosive growth and range expansion, causing extensive ecological and economic damages (U.S. Geological Survey 1998).

There is no question that the total number of harmful nonindigenous species and their cumulative impacts create a growing economic burden for the country, not to mention the unassessed monetary costs incurred by environmental impacts. Prevention and control initiatives must continue to be developed and implemented to manage harmful nonindigenous species and the damages they cause.

Institutional Framework for the Prevention and Control of Nonindigenous Aquatic Nuisance Species

The prevention and control of nonindigenous invasive species have global implications that require policies and programs at various levels of government. The following section provides an overview of the prevention and control programs targeting nonindigenous aquatic nuisance species. Because prevention and control programs for nonindigenous terrestrial species have not been developed to the extent of ANS programs, terrestrial management structure is not addressed in this section. As illustrated in the following discussion on ANS management, coordination among federal, regional, state and local programs is critical to effectively address problems caused by the introduction and spread of both aquatic and terrestrial nonindigenous species.

Federal Role

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990: The enactment of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA, Public Law 101-646) has provided federal legislative support for programs aimed at ANS prevention and control. NANPCA's enactment was largely due to the unintentional introduction of the zebra mussel and its subsequent economic and ecological impacts. Although the zebra mussel invasion of the Great Lakes has played a central role in prompting passage of the federal legislation, NANPCA was also established to prevent the occurrence of new ANS introductions and to limit the dispersal of nonindigenous aquatic nuisance species already in U.S. waters.

In drafting the act, Congress recognized that effective mitigation of ANS problems is dependent upon a well-coordinated research, monitoring and prevention program at both the regional and national level. As enacted, the legislation has five purposes: to prevent unintentional introductions; to coordinate research, control and information dissemination; to develop and carry out environmentally sound control methods; to minimize economic and ecological impacts; and to establish a research and technology program to benefit state governments.

Under NANPCA, the Great Lakes basin became the first geographic location where federal legislation established a regulatory regime that targeted the prevention of ANS introductions carried in ballast water. A Great Lakes program developed to implement and enforce U.S. regulations (at 33 CAR 151 Subpart C), as required through mandatory compliance with NANPCA, was enacted in May of 1993. These regulations stipulate that vessels bound for the Great Lakes exchange freshwater ballast with open-ocean salt water that contains organisms not likely to survive in freshwater. Enforced by the Canadian Coast Guard and Seaway authorities, the regulations require that the level of salinity in ballast water equals or exceeds 30 parts per thousand (ppt). (The salinity of normal sea water ranges from 34 to 36 ppt). Compliance with the requirements of the regulations can be met with one of the three options: 1) ballast water exchange at sea beyond the Exclusive Economic Zone of either the U.S. and Canada in a depth of at least 2,000 meters; 2) retaining the vessel's ballast water onboard during the entire voyage within the Great Lakes; or 3) implementation of an alternative environmentally sound method of ballast water management that must be first approved by the U.S. Coast Guard.

Although the regulatory regime on ballast water under NANPCA addresses a portion of the problem, it does not deal "NOBOBs,," vessels entering the lakes reporting "no ballast on board." Although NOBOBs do not contain pumpable ballast in their tanks, they do carry considerable residual ballast in the form of sediment that is present even after a complete discharge operation. The organisms carried in the residual sediment may be discharged when water is added to the ballast tank and later released into the lakes from vessels with multiple destinations in the basin. It has been recognized that a large number of vessels entering the Great Lakes carry unpumpable ballast, and additional regulatory action may prove necessary to strengthen the regulatory regime established under NANPCA (Reeves 1999).

Aquatic Nuisance Species Task Force: The national Aquatic Nuisance Species Task Force, established under Section 1201 of the 1990 legislation, is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species and implementing NANPCA. The Task Force is co-chaired by the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration and was established to coordinate governmental efforts related to nonindigenous aquatic species in the United States with those of the private sector and other North American interests. The Task Force consists of seven federal agency representatives and 10 ex-officio members. The other federal agencies are the U.S. EPA, U.S. Coast Guard, the Assistant Secretary of the Army for Civil Works,U.S. Department of Agriculture (USDA) and U.S. Department of State (Aquatic Nuisance Species Task Force 1994).

Under Section 1202 of NANPCA, the Task Force adopted the cooperative Aquatic Nuisance Species Program. The ANS Program addresses all new nonindigenous aquatic species activities that are conducted, funded, or authorized by the federal government, except those involving intentional introductions. It seeks to complement effective existing nonindigenous species activities rather than supplant them. The ANS Pogram recommends the following essential elements:

- **Prevention**: Establish a systematic risk identification, assessment and management process to identify and modify pathways by which nonindigenous aquatic nuisance species spread.
- **Detection and Monitoring:** Create a *National Nonindigenous Aquatic Nuisance Species Information Center* to coordinate efforts to detect the presence and monitor the distributional changes of all nonindigenous aquatic nuisance species, to identify and monitor native species and other effects, and to serve as a repository for that information.
- **Control**: The Task Force or any other potentially affected entity may recommend initiation of a nonindigenous aquatic nuisance species control program. If the Task Force determines that the species is a nuisance and control is feasible, cost-effective and environmentally sound, using a decision process outlined in the control program, a control program is eligible for approval.

Support elements include research, education and technical assistance. The ANS Program coordinates research efforts, establishes protocols and allocates grants. Education activities relate to encouraging and facilitating efforts to inform and educate a wide range of audiences about the problems caused by nonindigenous species. Technical assistance ensures the coordinated application of existing capabilities. Other related activities include coordinating the zebra mussel program, review/approval of state ANS management plans, voluntary guidelines and regulations on ballast water, and shipping initiatives to control nonindigenous species, and biological studies on the impacts of nonindigenous species.

The Task Force also provides national policy direction as a result of protocols and guidance that have been developed through the efforts of the following working committees: Research Protocol/Coordination, Intentional Introduction Policy Review, Great Lakes Panel on Aquatic Nuisance Species, Ruffe Control, Risk Assessment and Management, Detection and Monitoring, Zebra Mussel Coordination, Brown Tree Snake Control Committee and Recreational Activities Committee.

National Invasive Species Act of 1996: NANPCA was reauthorized through the National Invasive Species Act of 1996 (NISA, P.L. 104-332), and signed into law in October 1996. NISA expands the ballast management program to be national in scope and enhances other national monitoring, management and control programs. Some noted progress achieved through the reauthorized legislation include:

- Creation of an enforceable national ballast management program targeted to all U.S. coastal regions
- Requirement of detailed ballast exchange reporting by all vessels
- Reauthorization of the mandatory Great Lakes ballast management program;
- Authorization of a *Ballast Technology Development Program* to investigate technological and management tools to replace ballast exchange
- Continuation and expansion of the comprehensive state management plan program to include an aquatic plants program
- Authorization of funding for research and development of a dispersal barrier for the Chicago Ship and Sanitary Canal to help prevent transfers of organisms between the Great Lakes region and the Mississippi River basin,
- Creation of voluntary national guidelines for recreational vessels to help prevent spread of nonindigenous aquatic species overland via trailered vessels
- Region-specific research on the effects of invasive species in the Gulf of Mexico, Narragansett Bay, Chesapeake Bay, Lake Champlain, the Great Lakes, California and the Pacific Coast, and Hawaii, and other regions yet to be determined (U.S. Congress 1996).

Under NISA, studies are assessing the effectiveness of various technologies for ballast water control. Open ocean exchange, in which ships empty and fill ballast water in near coastal waters, provides the best measure for ensuring that nuisance species are not transported. These waters are sufficiently different from inland waters, assuring that transported species do not survive. However, in practice, this is a potentially dangerous technique for the ship and crew. Another alternative is nearshore alternate exchange zones, although this does not work for all ship designs. Currently, the Gulf of St. Lawrence is the only one in operation. Here, ballast water is exchanged closer to shore, but still outside of freshwater. This technique is believed to be less effective. The retention of ballast on board is another control technique and requires moving ballast water to different areas of the ship while loading and unloading, however, shipping interests are resistant to this technique. There are other, less effective techniques available. These include avoiding the intake of ballast water near red algal blooms and visible sewage discharge, when possible. Despite these techniques, the problem remains of unpumpable residuals in which invasive species can be resuspended and later discharged. Future ballast management goals should aim at a more comprehensive array of tools, including coastal and transoceanic shipping and nearshore alternate exchange zones and pumping facilities (Cangelosi 1999).

NISA also supports other potential options to better manage ballast water introduction of invasive species. The legislation provides the opportunity to implement the monitoring of ballast water through U.S. Coast Guard compliance checks on a national scale. There is growing support for research and development for onboard and offboard treatment options, along with retrofitting and new design possibilities. This may also be the time to create new requirements for new ships, ensuring better ballast management practices. Finally, studies on the effectiveness of ballast exchange techniques need to be implemented. The techniques must be not only effective, but also monitorable, economically feasible, safe and applicable to non-transoceanic shipping. Current research is investigating the feasibility of heat, backwash filtration, biocides, shoreside treatment, cyclonic separation, ultraviolet light, ozonation and ultrasonics as treatment options (Cangelosi 1999).

Executive Order on Invasive Species: The most recent federal initiative, an executive order signed by President Clinton in early 1999, has the potential to give invasive species prevention and control efforts in the Great Lakes basin a higher profile and additional resources. The "Invasive Species" order, which will complement and build upon existing federal authority, seeks "to prevent the introduction of invasive species and provide for their control, and to minimize the economic, ecological and human health impacts that invasive species cause" (U.S. President Clinton 1996).

The executive order has three main features:

- A requirement that all relevant federal agencies use their programs and authorities to prevent the introduction of invasive species, detect and respond to new populations, undertake necessary monitoring, restore native species and habitats in affected ecosystems, conduct research and develop prevention strategies, and promote public education;
- The establishment of a federal interagency Invasive Species Council co-chaired by the secretaries of the Interior, Agriculture and Commerce, with members also including the secretaries of State, Treasury, Defense and the Administrator of the U.S. EPA. Among others, the council will oversee executive order implementation, promote interagency coordination and action, encourage ecosystem-based planning at all levels of government, and employ an Internet-based information system to advance prevention and control efforts. An advisory council comprised, in part, of state, regional and tribal representatives will assist;
- The issuance of an Invasive Species Management Plan to "detail and recommend performance-oriented goals and objectives and specific measures of success" for federal agency efforts.

By raising the profile of the invasive species problem, the executive order is welcome news to the Great Lakes region, where the Great Lakes Commission, Great Lakes Panel on Aquatic Nuisance Species, and many other agencies, organizations and research institutes have been working for a decade to elevate the profile of this insidious form of biological pollution. However, it will be critical to ensure that the Invasive Species Council and associated executive order provisions build upon, rather than compete with, existing infrastructure for invasive species prevention and control. For example, it is crucial that:

- The work, profile, role and funding base for the national ANS Task Force are maintained and enhanced;
- A strong regional presence (Great Lakes and elsewhere) on the Advisory Council of the Invasive Species Council is secured;
- NISA remains the linchpin for prevention and control efforts and is funded and implemented accordingly; and
- The Invasive Species Council takes advantage of proven coordination initiatives. For example, the Great Lakes Panel's model comprehensive management plan; model guidance on legislation, regulation and policy; and action plan may all have some relevance and transferability on a national scale as the Council develops its own management plan.

Regional and State Role

Great Lake Panel on Aquatic Nuisance Species: Under NANPCA, the ANS Task Force requested that the Great Lakes Commission convene the Great Lakes Panel on Aquatic Nuisance Species per Section 1203 of the Act. Since 1991, the Great Lakes Panel has worked to prevent and control the occurrence of aquatic nuisance species in the Great Lakes (see Figure 6). This has been a challenging task given that at least 146 known nonindigenous aquatic species have been introduced into the Great Lakes since the early 1800's (Mills et al.1993; Mills, pers. comm. 2000). Once introduced, the aquatic invaders must be managed and controlled, as they are virtually impossible to eradicate (U.S. Congress 1990). Panel membership is drawn from U.S. and Canadian federal agencies, the eight Great Lakes states and the provinces of Ontario and Québec, regional agencies, user groups, local communities, tribal authorities, commercial interests and the university/research community.

Figure 6. Responsibilities of the Great Lakes Panel under §1203 of NANPCA

- identify ANS priorities for the Great Lakes;
- make recommendations to the national ANS Task Force;
- coordinate ANS program activities in the Great Lakes that are not cited directly in the Act;
- provide advice to the public and private individuals and entities concerning aquatic nuisance control;
- prepare an annual report describing regional prevention, research and control activities in the Great Lakes Basin.

Source: Nonindigenous Aquatic Nuisance Species Prevention and Control Act of 1990

Establishment of the Great Lakes Panel has provided a long-standing body of regional experts that contribute substantially to information and education programming, research and management coordination, and legislative and policy initiatives. Effective prevention and control efforts in the Great Lakes region continue to be the first line of defense in slowing or preventing the spread of nonindigenous aquatic nuisance species to other regions (e.g., the Mississippi River watershed). Some of the Panel's most popular products are highlighted below:

- *Workshop Proceedings: Aquatic Nuisance Species and Coastal Management Programs: Toward a Regional Strategy in the Great Lakes Basin* (January 1996). A summary of a 1995 conference on approaches to strengthen regional policy on the prevention and control of aquatic nuisance species. The document includes a model comprehensive state management plan for use by the Great Lakes states in developing their own plans as called for in NANPCA.
- *Aquatic Nuisance Species Research Relevant to the Great Lakes Basin: Research Guidance and Descriptive Inventory* (February 1997). A comprehensive inventory that highlights current and recently-completed research on aquatic nuisance species relevant in the Great Lakes basin. Also included is research guidance that provide recommendations concerning research gaps and needs directed at agencies and institutions that conduct, manage, fund or apply ANS research.
- *Aquatic Nuisance Species Information and Education Materials Relevant to the Great Lakes Basin: Recommendations and Descriptive Inventory* (February 1997). A comprehensive inventory that highlights information and education materials on aquatic nuisance species in the Great Lakes basin. The document also provides recommendations for strengthening information and education efforts related to aquatic nuisance species in the Great Lakes basin.
- *Biological Invasions: How Aquatic Nuisance Species Are Entering North American Waters, The Harm They Cause and What Can Be Done To Solve The Problem* (August 1998). This brochure focuses on how aquatic nuisance species are entering North American waters, their environmental

and economic impacts, and recommendations on what can be done to strengthen prevention and control efforts. The brochure, which covers ANS problems on a national scale, includes a U.S. map as a centerpiece, illustrating examples of aquatic nuisance species that are particular problems around the country. Also featured are smaller distribution maps that show the states affected by selected problem species.

- *Aquatic Invaders* (August 1999). A video documentary produced by Information Television Network's TECHNO 2100 series, examines the threat posed by aquatic nuisance species and how scientists, policymakers and the public are working to prevent new introductions and control the spread of existing ones. The 30-minute special focuses on prevention and control efforts in the binational Great Lakes basin, highlighting the work of the Great Lakes Panel on Aquatic Nuisance Species and many federal, state, provincial, and university-based research and management initiatives. The challenges and opportunities in prevention and control are placed in a national and international context as well. The program, initially aired on CNBC on Aug. 14, 1999, has been be repeated at least 30 times over the year in primetime slots. Accessible to some 66 million U.S. and Canadian viewers, the program was produced by Information Televison Network in collaboration with the U.S. Environmental Protection Agency, the Great Lakes Commission, and numerous federal, state and provincial agencies.

<u>Regional Policy Initiatives Developed Under the Auspices of the Great Lakes Panel on Aquatic Nuisance Species</u>: Over the past decade, the Great Lakes Panel has played a significant role in the development of regional policy to advance priorities regarding ANS prevention and control, as reflected in NANPCA of 1990 and NISA of 1996. The policy initiatives highlighted below are based on consensus of the diverse array of stakeholders serving on the Panel, thus serving as effective an effective tool to address ANS problems on a regional basis.

- ***Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species: Model Guidance for Great Lakes Jurisdictions*** (June 1999).

The model guidance, developed as a product of the Great Lakes Panel, serves as a tool kit from which states, provinces, tribal authorities and local entities can select the legislative, regulatory and policy tools best suited to address ANS problems in their infested watersheds (see Figure 7).

The impetus for development of this regional model was the lack of interjurisdictional consistency in laws, regulations and policies directed at ANS prevention and control efforts. The Great Lakes Panel saw a need for regional policy to help familiarize the governing agencies in the Great Lakes region and elsewhere on ways to respond proactively to ANS problems due to the increased likelihood of introductions with the occurrence of greater international trade and travel.

For example, the model guidance recommends rules addressing the transport of watercraft from infested waters. Model language advises that boats must be properly drained, and any visible plants, animals and mud must be removed before the vessel is launched elsewhere. Another recommended regulation prohibits the diversion, appropriation or interstate transport of water taken from infested waters. Provisions pertaining to the movement of high-risk fishing gear from infested waters to uninfested waters call for the decontamination of gear by removal of plant material, animals and mud, along with freezing, drying, or use of separate gear as decontamination options. Other regulatory tools recommended in the

Figure 7. The Primary Building Blocks of the Model Guidance

- designation of management authority
- a four-tiered classification system for nonindigenous aquatic species (prohibited, regulated, unregulated and unlisted species) and criteria to guide in the classification process
- designation of infested waters and activities subject to regulated/prohibited activities in infested waters
- permitting and regulatory protocol pertaining to beneficial uses of nonindigenous aquatic species
- ANS inspection programs
- establishment of enforcement
- authority and related penalties, and
- protocol for an ANS emergency action plan

Source: Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species 1999

model guidance address beneficial use operations involving aquatic nuisance species, such as the live-bait industry, aquaculture trade and horticultural business. Appendices are included as part of the document regarding state and federal legislation and regulations that were instrumental in the development of the model guidance.

The model guidance strives to enhance consistency in terms of legislation, regulation and policy that incorporate key ANS prevention and control provisions among Great Lakes jurisdictions. A multi-watershed, interjurisdictional approach is essential in managing invasive species since their points of origin span both the country and the globe. It is not expected that the model guidance will be used as an "all or nothing" proposition, but rather as a map to guide Great Lakes jurisdictions towards achieving a higher level of consistency regarding their legislative, regulatory and policy mandates to prevent ANS introductions and dispersal. The Panel's work on the model guidance reflects the long-standing commitment of this regional body to mitigate problems stemming from biological invasions in Great Lakes waters (Great Lakes Panel on Aquatic Nuisance Species 1999).

- ***Ballast Water Management and Aquatic Nuisance Species: Setting a Research Agenda for the Great Lakes*** (March 2000).

The Great Lakes Panel on Aquatic Nuisance Species sponsored a symposium in 1999 which grew from consensus on the need to prevent new ANS introductions and a recognition that ballast water is a significant source of such introductions in the Great Lakes basin. Symposium participants reviewed current approaches to ballast water management, assessed prospective technologies and management approaches, and established associated research priorities. Using this input, Panel staff at the Great Lakes Commission developed detailed findings and recommendations summarized below:

- **Ballast Exchange**: Open-ocean ballast exchange currently is the primary approach to preventing ANS introductions via ballast water. It has proven inadequate, however, and also poses serious safety concerns for some vessels. Symposium participants recognized that it will likely remain in use for some time and may ultimately be combined with other management approaches and technologies. The impacts, effectiveness and safety of ballast exchange needs to be better understood. The effects of exchange on different classes of ships must be assessed and design standards are needed to ensure it can be conducted safely.

- **NOBOBs**: Most vessels entering the Great Lakes report "no ballast on board" (NOBOB) and are not required to conduct open-ocean ballast exchange. They still carry residual slop and sediment that may be a source of ANS introductions. The risk posed by NOBOBs must be better understood, including the suite of organisms that remain in their ballast tanks. Among others, potential treatment options to be explored include shoreside facilities, chemicals, heat and partial exchange. Environmental and safety impacts from chemicals must be carefully evaluated.
- **Evaluating Research Proposals**: Ballast water research and development activities are being conducted by numerous public and private entities. Consensus is needed on criteria to guide and evaluate these efforts. Some specific issues that research projects should address include operational feasibility, safety, costs, environmental impacts and biological effectiveness.
- **Pathogens in Ballast Water**: The presence of pathogens in ballast water and their potential threat to public health merit greater attention. The nature and scope of the risk should be assessed, along with the risk that fish pathogens may pose to Great Lakes fishery resources.
- **Ballast Water Standards**: Standards, criteria and regulatory guidance for ballast water management options are needed to guide policymakers, industry and the research community. Some critical issues are safety, biological effectiveness, operational feasibility and costs. Improved methods for ensuring compliance are needed, as well as protocols for assessing the biological effectiveness of treatment technologies and management approaches. Different regions and classes of vessels may have varying needs.
- **Costs and Economic Impacts**: Substantial uncertainty exists concerning costs and economic impacts of alternative ballast water technologies. These costs must be balanced against the impacts of exotic species, however. The potential costs of ballast management technologies need to be documented both for new vessels and for retrofitting existing vessels. Impacts to Great Lakes maritime commerce should also be evaluated, along with options for mitigating ballast water costs to the shipping industry.
- **Communication, Coordination and Collaboration**: The ballast water "community" is large and diverse. Ongoing communication and coordination among all parties is critical. The community involved in ANS prevention and control should build relationships with the shipping industry and take advantage of resources available at universities and government laboratories to evaluate ballast management technologies. A stronger understanding of ballast management also must be cultivated among elected officials in efforts to promote support for further research. Finally, the Great Lakes region and the U.S. and Canada generally, should participate in the International Maritime Organization's policy work on ballast water management.

- ***A Great Lakes Action Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species*** (May 2000)**.**

The Great Lakes Action Plan and associated addendum provides vision on a regional basis to advance the laws, agreements and programs established to address ANS impacts. The Action Plan – a concise statement focusing on goals and principles – has been forwarded to the Great Lakes St.-Lawrence governors and premiers for their signature (as of June 2000). The addendum – a more detailed statement presenting associated objectives and strategic actions – has been endorsed at the Panel member level.

The Action Plan also presents 10 principles to guide programs in the region. They recognize that prevention and control are shared responsibilities involving multiple levels of government and the entire binational Great Lakes-St. Lawrence community. They recognize that success is fundamentally dependent upon comprehensive, multidisciplinary research, a coordinated and responsive management structure, and an informed, and involved public. Significantly, the principles recognize that this is not just a Great Lakes issue; jurisdictions within and outside this region share responsibility, given the interconnectedness of hydrologic basins (and vectors of introduction) in North America.

The addendum's 11 objectives and 36 strategic actions support these principles and are organized under the categories of management programs; research and monitoring; and information, education and collaboration. All items are practical and pragmatic; they are measurable outcomes by which progress can be assessed over time. For example, one calls for the establishment of a regional emergency response procedure for new introductions. Another calls for the establishment of ballast water standards and criteria to evaluate associated technologies and management practices. Yet another calls for a regional monitoring regime to provide early detection of new introductions.

The primary purpose of the Action Plan, which advances the goals of the comprehensive state ANS management plans (refer to section below), is to enhance focus on the ANS issue at the highest levels of state and provincial government to achieve the following:

- Timely and aggressive multijurisdictional response to documented new introductions;
- Adequate funding over the long term to meet prevention and control goals;
- Elevation of the issue of biological pollution within the individual and collective Great Lakes jurisdictions.

The ultimate intent of the Action Plan is reflected in the plan's vision statement, "We . . . envision healthy aquatic ecosystems where new introductions of nonindigenous aquatic nuisance species are prevented, and adverse ecological and economic impacts of species already present are minimized."

- ***A Model Comprehensive State Management Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species*** (January 1996). (Refer to section below on comprehensive state management plans.)

<u>Comprehensive State Aquatic Nuisance Species Management Plans</u>: The role of state entities regarding ANS prevention and control is specifically addressed under Section 1204 of NANPCA. The legislation calls for the development and implementation of comprehensive state management plans for ANS prevention and control. Section 1204 requires that the management plan "identifies those areas or activities within the state, other than those related to public facilities, for which technical and financial assistance is needed to eliminate or reduce the environmental, public health and safety risks associated with aquatic nuisance species." The content of each state plan is to focus on the identification of feasible, cost-effective management practices and measures to be pursued by state and local programs to prevent and control ANS infestations in a manner that is environmentally sound. As part of the plan, federal activities are to be identified for prevention and control measures, including direction on how these activities should be coordinated with state and local efforts. Section 1204 also states that in the development and implementation of the management plan, the state needs to involve appropriate local, state and regional entities, as well as public and private organizations that have expertise in ANS prevention and control (U.S. Congress 1990).

The state management plans are to be submitted to the national ANS Task Force for approval. If the plan meets Task Force requirements, the plan becomes eligible for federal cost-share support. If not, the plan is returned to the state with recommended modifications. Plans may be implemented with other funds supplied by state and cooperative agencies. Further details on the state management plans can be found in Section 1204 of the act (U.S. Congress 1990).

The Great Lakes Panel has provided a model to serve in the development and implementation of comprehensive state management plans for the states in the Great Lakes basin and other regions in the country. *A Model Comprehensive State Management Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species* was structured to address different stages of ANS invasion: 1) the introduction of nonindigenous species transported from water bodies from other parts of the continent or world; 2) the spread of established, reproducing ANS populations to other water bodies and 3) the colonization of ANS populations within water bodies, including the harmful impacts resulting from colonization.

The three goals on which the model state management plan is based are as follows:

- Prevent new introductions of nonindigenous aquatic nuisance species into the Great Lakes and inland waters of the state;
- Limit the spread of established populations of nonindigenous aquatic nuisance species into uninfested waters of the state;
- Abate harmful ecological, economic, social and public health impacts resulting from infestation of nonindigenous aquatic nuisance species.

The model state management plan, through its recommended goals and associated strategic actions and tasks, has been a popular tool used to guide state agencies in the Great Lakes region and beyond in the development of state, as well as interstate, management plans for ANS prevention and control. The state management plans in the Great Lakes region approved thus far by the national ANS Task Force include Illinois, New York, Michigan and Ohio. The interstate plans approved include the St. Croix River basin (Minnesota and Wisconsin) and Lake Champlain basin (New York and Vermont). The province of Québec has a management plan to address ANS issues, although the plan is not part of the U.S. approval process. The summary presented in Table 2 provides a status report on the management plans that are being developed or implemented in the Great Lakes region.

Table 2. Summary of Great Lakes State/Interstate Management Plans

State	Management Plan Status / ANS Task Force Approval Date	Plan Priorities
Illinois	The Illinois State Comprehensive Management Plan (February 18, 2000).	information/education (initial), prevention through regulations (subsequent)
Indiana	Agency support exists for the state management plan which is in early stages development.	
Michigan	Nonindigenous Aquatic Nuisance Species State Management Plan: A Strategy to Confront Their Spread in Michigan (April 1996).	prevention of unintentional introductions through ballast management; coordinate research, control efforts and information dissemination; minimize economic/ecological impacts, develop environmentally sound control mechanisms
a) Minnesota b) Minnesota/ Wisconsin	a) Plan development is in process with ongoing ANS program since 1991. Species-specific management plans have been adopted, as well as enforcement and information/education plans. b) The St. Croix National Scenic Riverway Comprehensive Interstate Management Plan for the Prevention and Control of Nonindigenous Aquatic Nuisance Species (Spring 1998).	a) public awareness, control, watercraft inspections, regulations and enforcement b) regulatory approach to prevent zebra mussel establishment in the St. Croix River; public awareness, including watercraft inspection at water accesses
a) New York b) New York/ Vermont	a) Nonindigenous Aquatic Species Comprehensive Management Plan (March 1, 1994). b) Lake Champlain Basin Aquatic Nuisance Species Management Plan (May 21, 2000).	a) monitoring, education/outreach and control. b) information gathering, management option evaluation, control strategies, public awareness
Ohio	Ohio State Management Plan for Aquatic Nuisance Species (1997).	national and regional coordination, interagency and constituent group coordination, outreach/education, monitoring, control, research, regulations and enforcement
Pennsylvania	State plan is under discussion by the Fish & Boat Commission and Dept. of Agriculture, the lead agencies for ANS issues. Plan development will require cooperation between these two agencies, each with its own mandate regarding enforcement/permitting.	
Wisconsin	a) State management plan draft completed and awaiting interagency approval from the Dept. of Agriculture, Trade and Consumer Protection, and the DNR. b) Interstate management plan (see Minnesota).	a) prevention through ballast water management, bait industry and aquaculture, monitoring to limit ANS spread, information/education, biotic control of aquatic weeds
Québec	Québec Action Plan on Zebra Mussels and Other Nonindigenous Aquatic Nuisance Species (Plan Dates: 1998-2003).	information/education, regulation, changes and research.

Management Strategies to Mitigate Nonindigenous Invasive Species

Problems

Prevention of Introductions and Dispersal

The prevention of new introductions of nonindigenous aquatic species is widely accepted as the most effective way to manage ANS problems and is considered the first line of defense against invasions. The following discussion, an excerpt taken from the ANS Task Force's Aquatic Nuisance Species Program, provides an overview on preventing the introduction and dispersal of nonindigenous aquatic nuisance species:

> Preventing the initial introduction and subsequent dispersal of nonindigenous aquatic species, collectively referred to as "prevention" is central to the (Aquatic Nuisance Species) Program. This program element includes measures to minimize the risk of unintentional introductions of nonindigenous aquatic species that are or could become nuisances. Anticipating and avoiding problems rather than reacting once a nonindigenous aquatic nuisance exists is the focus of this element and a cornerstone of the Program.
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> In the absence of effective prevention efforts, many additional nonindigenous species are likely to be introduced. Some are likely to adversely impact human activities or harm receiving ecosystems at levels that rival those encountered with the zebra mussel. Numerous control efforts with undesirable environmental or other consequences which would otherwise be unnecessary will be implemented in response to such introductions.
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> In the Act [NANPCA], preventing the spread of nonindigenous aquatic species from infested areas is included in the Control Element. Concepts and techniques for preventing the introduction of exotic species from overseas as well as other parts of North America are similar to those employed to prevent the dispersal of nonindigenous species after they are established in new ecosystems. Consequently, this aspect of control is included in the Prevention Element.
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> An epidemiological model is the basis for the Prevention Element. When viewed in the context of this model, prevention could focus on:
>
> - all nonindigenous aquatic species that could be introduced;
> - all environments into which they could be introduced; or
> - pathways that connect ecosystems and allow the movement of viable
> - aquatic organisms from place to place.
>
> Interruption of pathways is the most feasible and effective approach for preventing unintentional introductions and subsequent dispersal of nonindigenous species. Focusing on pathways concentrates action on the most easily disrupted element of the system. The number of pathways is much more limited than the number of locations (i.e., environments) or species. Nevertheless, targeting pathways remains a large task that will require substantial effort.

Targeting high risk pathways is one approach that is considered in the prevention of unintentional ANS introductions. These pathways have been summarized in Figure 8.

Figure 8. High-Risk Pathways of Unintentional ANS Introduction

- shipping (ballast water and sediments, anchor chains, sanitary waters, hull surfaces)
- relocation of floatable oil/gas drilling rigs, dry docks, navy tenders
- recreational boating (hull surfaces, bait wells, bilge water and sediments, motors, associated tools, equipment, fishing gear)
- media, containers and equipment used to transport or store live organisms (e.g., aquarium fish, plants, bait, aquaculture fish, fish stocking, research specimens, ornamental plants, pathogens)
- fresh or frozen seafood transport and disposal
- human-created water connections (navigation canals, e.g., Erie and Welland Canals)
- interbasin water transfers (e.g., irrigation)
- municipal/industrial water supply
- natural pathways (e.g., waterfowl, tornadoes, hurricanes, other storms).

Source: ANS Task Force's Aquatic Nuisance Species Program (Table 2, page 16)

Ballast Water Management: Ballast water has been identified as a major pathway for the introduction and dispersal of nonindigenous aquatic nuisance species (U.S. Department of Transportation, U.S. Coast Guard 1997). In an effort to prevent new introductions of nonindigenous aquatic nuisance species, ballast water management guidelines have been established as federal law in the Great Lakes under NANPCA of 1990. The U.S. Coast Guard issued regulations in May 1993 that required vessels bound for the Great Lakes comply with one of the following options: 1) exchange their water, if possible, on the high seas (in depths greater than 2,000 meters or 6,600 feet) to achieve a minimum salinity of 30 parts per thousand; 2) retain the vessel's ballast water onboard during the entire voyage withing the Great Lakes; 3) implementation of an alternative environmentally sound method of ballast water management approved by the U.S. Coast Guard.

Problems have arisen with open ocean ballast exchange ranging from limited effectiveness to concerns about crew and ship safety. There is also a significant problem with the unpumbable ballast residue for which regulations do not yet exist. It has been found that current ship designs leave a residual amount of ballast water in the tanks after a complete discharge operation. As a result, the organisms carried in the unpumpable ballast residue may be discharged when water is added to the ballast tank and later released into the Great Lakes from vessels with multiple destinations in the basin. It is also important to recognize that ballast regulations should not be expected to cease all future invasions, but rather, ballast regulations can only be expected to diminish the number of new invasions into the Great Lakes.

In reauthorizing the federal ANS legislation, NISA of 1996 establishes a national ballast management program that strengthens regulations on ballast water management in continued efforts to minimize ANS introductions. The national program, targeted to all U.S. coastal regions, will become mandatory if the shipping industry shows a record of poor compliance under a voluntary system. Compliance records will be established by way of a mandatory reporting system established and monitored by the U.S. Coast Guard. The ANS Task Force is responsible for developing criteria for how much compliance is needed to protect coastal resources. The Great Lakes ballast program remains unchanged (and mandatory) except that the scope of the program is clarified to include vessels which may enter the lakes reporting no ballast on board. NISA provides for authorization of a Ballast Technology Development Program which will bring additional resources to investigate the technological and management options of ballast water treatment (e.g., thermal, ultraviolet, chemical, ultrasound, filtration, etc.) to replace ballast exchange

(Cangelosi 1997).

Prevention of Nonindigenous Species Invasions through Quarantine Controls: To restrict the movement of nonindigenous invaders across political boundaries, the quarantine approach has been established as protection against species that threaten human, animal or plant life. The primary goal is to invest in inspection and exclusion of nonindigenous species to avoid the astronomical cost and effort that is incurred by control after populations have become established.

In the United States, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) is primarily responsible for agricultural quarantine and port inspection. Regulations under the U.S. Fish and Wildlife Service and Public Health Service restrict entry of injurious fish and wildlife and potential human disease vectors. However, the quarantine controls imposed in this country take an "innocent until proven guilty" approach; nonindigenous plants that are not known to be weeds are allowed entry. Harmful nonindigenous species can continue to be imported legally until added by regulation to a published list, a process which is often difficult and time consuming (U.S. Congress, Office of Technology Assessment 1993).

The quarantine approach practiced in the United States, however, has proved to be "inadequate to stem the tide of entering nonindigenous organisms" (Mack et al. 2000). Consequently, APHIS is considering policy changes that would conduct risk assessments estimating the "invasive potential" of a species proposed for import. In 1997, the Australian Quarantine Inspection Service adopted such a risk assessment system for screening new plant imports based on biological attributes and the consequent potential for invasion. This approach can result in restricting species introductions that in reality are innocuous and would not become nuisance species. It also should be noted that such a policy could generate conflict between environmentalists and commodity groups, such as horticulturists, advocating liberal NIS introductions. The challenge for scientists and policymakers lies in the development of a preventative approach that excludes the few potentially harmful invaders among a plethora of innocuous nonindigenous species (Mack et al. 2000).

Prevention of New Introductions by Predicting Potential Nonindigenous Invasive Species and Communities Vulnerable to Invasion: Despite the progress that has been made in documenting ecological and economic impacts resulting from introduced species, little attention has been focused on forecasting the unplanned invasions in North American freshwater habitats. One approach to the prevention of future ANS introductions is the identification and risk assessment of potential nonindigenous invaders and those ecological communities at risk in terms of invasion. This information can be applied to the development of criteria to prioritize management resources for the detection and control of potential invaders. To work towards a more proactive approach for ANS prevention and control, identification of potential future aquatic invaders and vulnerable communities is an approach deserving serious attention.

To make this predictive approach cost-effective, it is recommended that rather than compiling a comprehensive list, the focus should be directed toward the identification of potential invaders and vulnerable communities with "exceptionally high invasion and impact potential" (Ricciardi and Rasmussen 1998). The following guidelines are proposed for this selection process:

- **Potential donor regions and dispersal pathways**: 1) Updated nonindigenous species lists (e.g., Mills et al. 1993) could provide information on potential geographic donor regions where disproportionate numbers of successful invaders, as listed, have originated. 2) Potential donor regions may also be identified by large-scale shipping patterns with the ports acting as distribution hubs for both cargo and nonindigenous species. 3) The presence of strong dispersal pathways and vector activity between the potential donor and target regions may indicate a high probability of future invasions. For example, repeated ballast water discharges by European shipping using the St. Lawrence Seaway is held accountable for more than 30 percent of the Great Lakes invasions. Similarly, an increase in net tonnage of ships arriving from East Asian ports over the past three decades has coincided with introductions of a variety of Asian invertebrate introductions. An analysis of shipping traffic from regions containing known invaders such as the zebra mussel (Great Lakes) or the Japanese crab *(Hemigrapsus sanguineus)* (Long Island Sound) could help predict where these species will next invade.

- **Biological criteria**: Biological attributes of nonindigenous species could be used as a predictive tool for successful invasion. Some hypothesized attributes of successful aquatic invaders include: 1) abundance and wide distribution in original range, 2) wide environmental tolerance, 3) high genetic variability, 4) short generation time, 5) rapid growth, 6) early sexual maturity, 7) high reproductive capacity, 8) broad diet (opportunistic feeding), 9) gregariousness, 10) possession of natural mechanisms of rapid dispersal, and 11) dispersal mechanisms that involve human activity. For example, evidence indicates that successful invasions are probable for species possessing a number of these characteristics, such as high reproductive capacity, wide environmental tolerance limits and natural mechanisms for rapid dispersal, as is the case with the zebra mussel and the round goby. Studies of herbaceous plants have shown that the size of the current distribution of a species is often a good predictor of invasiveness. Examples of wide spread distribution include the water hyacinth and purple loosestrife. One attribute viewed as significant in predicting invasion potential is the species tendency to use human activity as a dispersal mechanism. For instance, many invasive bivalves and crustaceans possess planktonic larvae that are more easily transported in ballast water. Therefore, it is recommended that predictive profiles focus on the ability of an organism to exploit ballast water transport.

- **Invasion history as a predictive criterion**: Predictions also can be made based on past invasion history. It can be assumed that a nonindigenous species with a successful record of invasion will continue to invade elsewhere if conditions permit and opportunities arise. This predictive tool, coupled with a species ability to facilitate human-mediated dispersal mechanisms, such as transoceanic shipping, provide a basis for forecasting future invasions. Using this method, Mills et al. successfully predicted the invasion of the Great Lakes by *P. antipodarum,* a snail with an extensive invasion history in Europe, which was recently reported from Lake Ontario.

- **Community vulnerability to invasion:** Those communities that are relatively "impoverished" in terms of quantity of native species can be weakened in their biological resistance to invaders. In 1958 Charles Eton proposed that community resistance to invasions increases in proportion to the number of species in the community. According to Elton, communities are considered more "stable" if they are "species-rich" (Mack et al. 2000).

  Another factor facilitating the invasion of nonindigenous species is that upon establishment in new habitats, the invaders are "liberated" from their usual competitors, predators, grazers and parasites. This "escape from biotic constraints" can translate into a significant advantage for the growth, longevity and fitness of nonindigenous species. This hypothesis explaining the success of invaders has motivated researchers to search for biological control agents among invasive species' enemies in their native habitats (Mack et al. 2000).

> Disturbance of habitat is also considered a factor that can set the stage for biological invasions. Such disturbances can be caused by fire, flooding, agricultural practices, livestock grazing, drainage of wetlands, and alterations of salinity or nutrient levels in streams and lakes. New disturbances or intensification of natural disturbances have caused significant biotic invasions, including extensive plant invasions across vast temperate grasslands in North America. A variation on this theme is that a community may be better equipped to resist invasion if the ecosystem structure remains intact. For instance, forest communities may be more resistant to plant invasion as long as the different levels of the canopy are not disturbed (Mack et al. 2000).

Although there are not many documented results on the effectiveness of this predictive management approach for ANS prevention, it deserves careful consideration as an additional tool to prevent future ANS introductions.

<u>*Ballast Water Research Explores Potential of Glutaraldehyde in Prevention of ANS Introductions*</u>: (Submitted by Russ Moll, Michigan Sea Grant, based on a feature article in the *ANS Update*, 1998, Volume 4, No. 1.) Many of the ballast management technologies under investigation are not biologically effective, economically feasible and/or require substantial engineering modifications to ships. One option that has yet to be explored is a class of compounds called non-oxidizing biocides; one of these compounds that shows considerable promise is glutaraldehyde, a chemical that is very effective in the control of microorganisms at a concentration of 10 to 25 parts per million. This chemical has a short half-life of one to two days and then breaks down into harmless byproducts such as carbon dioxide.

The use of glutaraldehyde shows potential for NIS prevention and control in that it already has a wide range of applications that are environmentally acceptable. Most notably is its use as a sterilant in the medical and dental professions and to control microorganism growth in cooling water towers. The fact that glutaraldehyde is effective at low concentrations, yet breaks down quickly, makes it a good candidate for additional environmental applications. Although this compound is relatively expensive, its use in the treatment of unpumpable ballast should prove economically feasible (per application costs of $260 to $900 depending on the amount of residual ballast) since it will be needed in much smaller quantities than would be necessary to treat full ballast tanks.

Examining the feasibility of using this chemical to effectively treat ballast residue without posing environmental risks is the primary objective of this research project, conducted by investigators at the University of Michigan, and supported by a $300,000 grant from the Great Lakes Fishery Trust, an organization supporting Great Lakes research. The project is based on recommendations from a preliminary study funded by the Michigan Department of Environmental Quality's Office of the Great Lakes.

Primary investigators include Dr. Russell Moll, an aquatic biologist and director of the Michigan Sea Grant Program; Dr. Michael Parsons, a professor in the Naval Architecture and Marine Engineering Department, University of Michigan; and Larissa Lubomudrov, a graduate student in the School of Natural Resources and Environment, University of Michigan. The first year of the three-year project will be lab investigations to determine if glutaraldehyde can be used safely and effectively in treating ballast water. The second and third years will be actual shipboard investigations treating ballast tanks.

Use of a non-oxdizing biocide would entail only minimal engineering modifications to ships, making it a good candidate for use in the existing fleet while other technologies are being developed. Finally, the project will address if use of the biocide has any deleterious effects on the ship's crew or the ship itself. If this project proves a success, we may have a new weapon in preventing ANS introductions through ballast water.

Eradication and Control of Established Populations

Eradication (e.g., complete elimination) of NIS populations is sometimes feasible, particularly if detected early in the invasion process, at which point the number of individuals in the NIS populations is low and eradication measures are applied quickly. In reality, however, early detection of an infestation is unlikely due to insufficient ongoing monitoring, particularly in natural areas. Another obstacle to eradication is the tendency of regulatory agencies to overlook nonindigenous invasions for other priorities until the NIS problem has escalated out of control. To date, no success stories can be reported on total eradication of NIS invasions in the Great Lakes region.

Control of nonindigenous species at acceptable levels has been widely implemented due to the infeasibility of eradication. The three main approaches, applied independently or in various combinations, include chemical, physical/mechanical and biological control.

Chemical control effectively combat biotic invaders as illustrated by the use of the lampricide, TFM, in limiting the spread of the sea lamprey in the Great Lakes. Unfortunately, the use of chemical control frequently causes health hazards for humans and non-target species, as was the case with application of DDT. In addition, the evolution of pest resistance, the high economic costs and the need for repeated applications often make continued chemical control infeasible. Even in cases where human and ecosystem health hazards have not been documented, the perceived risk of chemical application inevitably generates public opposition, as has occurred with the proposed use of chemical treatments to contain the spread of the ruffe in western Lake Superior.

Physical/mechanical control of nonindigenous species has proven to be effective and usually does not generate public opposition. For instance, control of the invasive plant, *Phragmites*, has been achieved by cutting the aerial portion of the plant in mid-summer, when most of the food reserves produced for the season are removed, reducing the plant's vigor. In Great Lakes waters, mechanical harvesting of Eurasian watermilfoil has been successful. Harvesters mow milfoil weed beds by digging up the roots. Hand-pulling early in the season has also proven to be effective. Disadvantages to mechanical control are equipment expenses, difficulty in finding the target organisms and the large geographic scale that must be treated for effective control.

Problems with chemical and mechanical control have led to investigations involving biological control, i.e., the introduction of a natural enemy to prey upon a nonindigenous invasive species. In many cases, new invasives have escaped the biotic constraints of their indigenous habitat, thus experiencing a competitive edge in their newly invaded habitat. Biocontrol attempts to re-create such constraints through the introduction of a natural enemy that can compete with the target species, thus keeping its population in check. Some biological control projects have succeeded in containing very widespread, damaging infestations at acceptable levels with minimal costs. The ultimate goal is to introduce a perpetual mechanism of control that can be maintained without frequent human intervention. In the Great Lakes, a well known success story of biological control is the introduction of leaf-eating beetles to control purple loosestrife. Biological control, however, is pursued with caution due to concern that the predatory organisms may also have the potential to attack non-target species. The fact that biological control agents can disperse and evolve, as can any species introduced to a new range, makes extensive evaluation critical (Mack et al. 2000).

While control efforts have successfully limited the spread of some nonindigenous aquatic nuisance species, no known control options exist for others. The following discussion, an excerpt taken from the ANS Task Force's Aquatic Nuisance Species Program, provides an overview on the control of nonindigenous aquatic nuisance species. The Task Force is responsible for coordination of the development and implementation of ANS control plans.

> Control tends to be a focal point of many nonindigenous species initiatives. Exploration of control methods is frequently the initial response once a new nonindigenous species is detected or an established species begins to have a noticeable effect. However, this emphasis has become increasingly controversial with greater scrutiny of the efficacy and potential side effects of existing control programs.
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> Cooperative programs for control of established aquatic nuisance species are authorized, but not mandated (NANPCA, Subsection 1202(e)). The purpose of such control programs is to minimize harm to the environment and the public health and welfare. Control may be initiated without regard to the source of the introduction (i.e., intentional versus unintentional introductions) or when it was introduced. Control includes eradication of infestations, reductions in populations to some acceptable level, and adaptation of human activities and facilities to accommodate (i.e., work around) infestations. This includes efforts to protect native species and ecosystems likely to be adversely affected by infestations. Although preventing the spread of nonindigenous aquatic species is defined as control in the statute, this aspect of control is addressed in the Prevention Element of the Program. Given biological differences and the decision processes involved, control programs will tend to focus on specific species or groups of closely related species rather than applying to many types of organisms.
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> Aquatic Nuisance Species can be controlled by several general methods, including chemical, biological, mechanical or physical, and habitat management practices. Proper evaluation and use of selective chemicals may provide effective control of aquatic invaders with a minimum of ecological hazard or other side-effects. On the other hand, concern exists among biologists, public health interests and the general public about the environmental safety and long-term impacts of chemicals used to control aquatic nuisance species. Carefully planned biological control programs may provide rapid, cost-effective control while posing negligible ecological problems. However, 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 control of aquatic nuisance species, although often very expensive, can be the most appropriate technique in some circumstances. For instance, several engineering devices for power plants and other installations, including flushing affected areas with hot water, show considerable promise for reducing biofouling by zebra mussels. To protect native species and biodiversity, the establishment of refugia in natural habitats or artificial culture where aquatic nuisance species can be excluded or controlled may be necessary. Modifying natural habitats or other environments, such as water intakes, by changing management practices can prevent or reduce the effects of infestations.
>
> No single method is likely to provide the necessary control of aquatic nuisance species. Hence, a comprehensive control strategy involving a combination of techniques referred to as Integrated Pest Management (IPM) is usually necessary for an effective control program.
>
> Few, if any, control methods are without some environmental risk. However, when properly used, including continual monitoring for effectiveness and ecological side-effects, environmentally sound control of at least some aquatic nuisance species can be achieved.
>
> Affordable and effective control often requires a prompt response to an infestation before the organism becomes established or widely dispersed. Therefore, when a reasonable chance exists that a newly detected nonindigenous aquatic species could become a nuisance, a quick determination of whether control may be feasible and warranted is essential.

> The Task Force or any other affected agency or entity may recommend initiation of control (NANPCA, Susection 1202(e)). However, the Task Force itself will not conduct control programs. When a recommendation that control be initiated is received, the Task Force will ensure prompt and systematic evaluation of the proposal and, if warranted, approval of a control program.

Biological Control Measures in Fighting the Spread of Purple Loosestrife: Resource managers fighting the spread of purple loosestrife *(Lythrum salicaria)* have recently been armed with a biological control measure: tiny, imported beetles that graze on this invasive, perennial weed. Since its introduction to the U.S. in the early 1800s, loosestrife has invaded thousands of sites across the country, replacing native plant species by forming dense monotypic, stands in habitats such as wetlands, lakeshores, streams and ditches. In addition to threatening biological diversity and the ecological integrity of invaded sites, wildlife that depend upon native vegetation for food, shelter and breeding areas are forced to leave habitats invaded by purple loosestrife.

Purple loosestrife is an aggressive invasive weed with a single mature plant capable of producing up to two million seeds per year, which are dispersed along rivers and waterways. When introduced into North America from Eurasian habitats, purple loosestrife escaped the natural enemies that control its spread in its native range. There are no chemical or mechanical (e.g., cutting, burning, flooding) methods available to provide a long-term, sustainable management strategy for the species' control Infestations in small areas can be treated with herbicides, but large stands of loosestrife are very difficult to control. Biological control of purple loosestrife using host specific plant-eating beetles is showing potential in reducing large infestations on a long-term sustainable level that is both environmentally sound and economically feasible.

In the mid-1980s, the USDA hired European researchers to identify insects as potential controls of loosestrife. To qualify as a suitable biocontrol agent, the following criteria were considered: 1) host specificity of the insect (i.e., ability to survive and feed exclusively on purple loosestrife without posing a threat to native American plant species) and 2) cause the plant to die, reducing shoot growth, supressing flowering or reducing seed output. Researchers identified five insects with the greatest potential for biocontrol of the 120 species of insects associated with purple loosestrife. Those chosen include the rootboring weevil (*Hylobius transversovittatus*), two leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) and two flower feeding weevils (*Nanophyes marmoratus* and *N. brevis*). To increase the likelihood of success, the researchers chose insects that attack different parts of the plant, thus reducing it vigor and reproductive potential. The root-boring weevils attack the plant's roots, leaf-eating beetles defoliate and curtail flower production, and flower-feeding weevils destroy flowers and reduce seed production.

Eight years of testing revealed that these five species consume only loosestrife, the USDA approved them for release in the United States. It was considered a risk to introduce a living nonindigenous species into the environment. However in this case, the risk was considered low when compared to the negative impacts of purple loosestrife. However, the species *N. brevis* was later excluded as a biocontrol agent; it was found to carry a parasite, which was considered a significant risk to the ecosystem.

Management and Control of the Ruffe: (submitted by Tom Busiahn, U.S. Fish and Wildlife Service, chair, Ruffe Control Committee): Presence of the Eurasian percid fish, ruffe *(Gymnocephalus cernuus)* was detected in the Duluth-Superior Harbor on western Lake Superior in 1986. By 1991, ruffe had become the most abundant species in the harbor as measured by trawl sampling. A 1992 report by the Great Lakes Fishery Commission called ruffe "a threat to North American fisheries." Development of a Ruffe Control Program was authorized by the national ANS Force in 1992 and was approved by the Task Force in 1995. The goal of the program was to contain ruffe to western Lake Superior. After ruffe were detected in Alpena Harbor on Lake Huron in 1995, the control program was revised. The goal of the program, to prevent or delay further spread, has been met since 1995. The Ruffe Control Committee meets annually to oversee implementation of the control program. The control program and committee minutes may be accessed on the internet from: http://www.fws.gov/r3pao/ashland/.

The impacts of ruffe are a subject of scientific debate. Direct impacts on economically important sport or commercial fish have not been proven, but research indicates that ruffe cause profound changes in ecosystem energy flow. Simulation modeling indicates a lag time of decades in effects of ruffe on yellow perch *(Perca flavescens)*.

The known range of ruffe is nearly unchanged since 1995. Ruffe are abundant in estuaries of southwestern Lake Superior. Small reproducing populations occur in Thunder Bay, Ontario. on the north shore of Lake Superior, and in Thunder Bay, Mich., on the west shore of Lake Huron. However, peripheral ruffe populations have grown in recent years, portending future range expansion from those sites.

The Ruffe Control Program is comprised of eight components summarized below with a prognosis for future success.

- **Population Reduction**
  Objective: Eliminate or reduce reproducing populations using appropriate technologies, where feasible.
  Prognosis: Poor. Technologies do not exist. Piscicides are controversial and likely to be ineffective. Physical removal may be useful in very limited situations.

- **Ballast Water Management**
  Objective: Minimize the transport of ruffe from western Lake Superior through ballast water management, and support the development of technologies to prevent transport.
  Prognosis: Good for western Lake Superior ports. Poor when ruffe colonize other Great Lakes. Technology development is in very early stages.

- **Population Investigation**
  Objective: Continue and expand investigations of ruffe populations to evaluate the impact on affected fish communities and to provide information necessary to plan, implement and evaluate control activities.
  Prognosis: Mixed. Investigations continue at reduced intensity. Integration of agencies' data has not been completed.

- **Surveillance**
  Objective: Conduct surveillance sampling in likely locations to find newly established populations of ruffe, and designate a single office to compile collections of ruffe.
  Prognosis: Good. Field sampling and angler reports have detected ruffe colonization in a timely manner. Surveillance results for all Great Lakes are compiled into one annual report.

- **Fish Community Management**
  Objective: Recommend fish management practices that will improve resilience of fish communities against invasion or dominance by ruffe.
  Prognosis: Mixed. No recommendations specifically for ruffe. General recovery of Great Lakes fish communities and habitats will increase resilience.

- **Education**
  Objective: Develop and promote information and education programs to identify ruffe so that they will not be transported alive and so they will be killed and reported if taken.
  Prognosis: Good. Excellent educational materials are available. Public awareness is high.

- **Bait Fish Management**
  Objective: Assist jurisdictions in developing model language for regulation of bait harvest and possession.
  Prognosis: Good. Model language now available through Great Lakes Panel on Aquatic Nuisance Species (refer to the 1999 citation of the Great Lakes Panel: *Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species: Model Guidance for Great Lakes Jurisdictions*). Bait industry working to improve quality control.

- **Chicago Sanitary and Ship Canal**
  Objective: Consider options to prevent the movement of ruffe from the Great Lakes to the Mississippi watershed via the Chicago, Des Plaines and Illinois rivers.
  Prognosis: Mixed. Electrical barrier is to be installed in summer 2000. Effectiveness is unknown, and other technologies are poorly developed.

Overall prognosis: Activities conducted under the program have delayed the spread of ruffe in the Great Lakes. It is projected that, even in the absence of human-assisted transport to new locations, the ruffe will eventually colonize new locations throughout the Great Lakes and connected waters by their own movements. However, assistance by humans will be necessary for ruffe to colonize new locations beyond the Great Lakes and connected waters. Measures are being developed to prevent ruffe from being transported to waters not connected to the Great Lakes.

<u>Control of the Round Goby</u>: (submitted by Sandra Keppner, U.S. Fish and Wildlife Service.) The round goby (*Neogobius melanostomus*) was first collected in North American waters in 1990 in the St. Clair River. The goby is a bottom-dwelling fish that has great potential to impact the Great Lakes fishery. Round goby are thriving in the Great Lakes basin because they are aggressive, voracious feeders that can forage in total darkness. The round goby takes over prime spawning sites traditionally used by native species, competing with native fish for habitat and changing the balance of the ecosystem. Goby can also survive in degraded water conditions, and spawn more often and over a longer period than native fish. The round goby is already harming native bottom-dwelling Great Lakes native fish like mottled sculpin, logperch and darters.

Since 1990, the round goby has shown a rapid range of expansion to all five Great Lakes, including southern Lake Michigan, where it has become established in the Illinois Waterway System which provides a direct connection between the Great Lakes and the Mississippi River. Resource managers were alerted to the establishment of round goby within the waterway and recommendations were developed to install an electrical barrier to minimize the risk of further spread of round goby. These efforts are advancing with barrier construction expected to be initiated in August 2000. However, as of June 2000, the round goby range has expanded downstream on the waterway to Joliet, which is 50 miles inland from Calumet and 11 miles downstream from where the electric barrier will be constructed (Thiel pers. comm. June 2000) This range expansion has increased concern that implementation of the barrier may be too late to prevent the species from spreading to waters beyond the waterway, including the Illinois and the Mississippi rivers.

In late summer 1999, a workshop was convened by the Illinois Department of Natural Resources (DNR) in cooperation with the national ANS Task Force to evaluate short-term control strategies to minimize the risk of further spread of round goby throughout the Illinois Waterway System. Based on the outcome of the workshop, the Illinois DNR is investigating the feasibility of using a bottom-release formulation of the piscicide Bayluscide to eradicate round goby at the periphery of their range within the waterway. The agency, in cooperation with various state, regional, local and federal agencies, is addressing following four issues related to the application of this piscicide:

- **Permitting**: Currently, this piscicide is labeled as a lampricide for use in the Great Lakes Basin and Lake Champlain. If necessary, it may be possible to seek re-labeling for use as an emergency response. Other permitting requirements also are being investigated.
- **Funding**: Costs associated with purchasing and application of the piscicide are expected to be substantial.
- **Research**: The U.S. Geological Survey – Upper Midwest Environmental Sciences Center will conduct experimental analyses to determine the behavioral response of round goby to the bottom-release formulation of this pesticide. In addition, studies will be conducted to determine the required contact time of round goby to Bayluscide to achieve mortality. A multi-agency effort will be coordinated in September to collect 1500 round goby for experimentation.
- **Surveillance**: The U.S. Fish and Wildlife Service-La Crosse Fishery Resources Office will lead a multi-agency effort, known as the "Goby Round-Up" to re-affirm, on an annual basis, the extent of the round goby spread and determine current densities within waterways around Chicago. The most recent Goby Round-Up, was conducted in June 2000. Preliminary research indicates that the goby average more than four inches, doubling in length from samples taken in 1999. As mentioned above, since the initial sighting off Chicago in Lake Michigan in 1996, the goby has migrated into the Calumet River, through the Calumet Sag Channel, and south into the Des Plaines River as far down as Joliet, 50 miles southwest of Chicago.

<u>Aquatic Nuisance Species Dispersal Barrier for the Great Lakes and Mississippi River Basins</u>: (originally submitted by Phil Moy, formerly of U.S. Army Corps of Engineers and currently of Wisconsin Sea Grant, as a feature article for *ANS Update*, 1997, Volume 3 No. 4; updated in June 2000 by David Handwerk, U.S. Army Corps of Engineers): The Chicago Sanitary and Ship Canal has facilitated transportation and trade but removed geographic obstacles to the interbasin spread of nonindigenous aquatic nuisance species. The Chicago area waterway system provides a direct linkage between the Great Lakes basin and the Mississippi River basin. The round goby recently introduced into the Great Lakes in the ballast water of ocean-going vessels, is extending its range through this waterway. As of June 2000, this small, bottom-dwelling and very aggressive nonindigenous fish has migrated 15 percent down the length of the Illinois waterway and is well-positioned to invade warmer waters of the Mississippi River basin.

Activities on the canal involve multiple jurisdictions, permitting authorities, uses and interests. To address concerns over the downstream expansion of round goby populations, a barrier advisory panel was established, consisting of about 20 different federal, state, regional and municipal agencies and industry and environmental groups. The panel has identified potential approaches to an ANS dispersal barrier for the canal. The two constraints specified were that the barrier must not interfere with barge traffic nor affect the Lake Michigan diversion volume. Other obstacles affecting barrier design include variable flow (2,000 to 20,000 cfs), existing permit requirements to maintain water quality, recreational boating and public perception.

Of the many approaches considered, an electric field and the chemical treatment, rotenone, ranked highest; however, chemical treatment was recommended for limited use only. The panel decided that, in the short term, a barrier consisting of an electric field appeared to be the best approach to control the downstream spread of the goby.

The goby dispersal barrier will be located downstream at river mile 296, which, in the initial phases of the project (September 1999), was the farthest point of the goby's range. The goby, as of June 2000, has been sited eleven miles downstream from where the barrier will be constructed. The barrier will consist of two pulsed direct current arrays, each extending across the canal and located approximately 300 meters apart. Each array will generate an electrical field effective to a height about 2 meters above the canal bottom, posing no threat to human safety. The barrier will be attached to the bottom and recessed into the sides of the canal so that barge traffic can continue to operate normally. The electric field can be modified to adapt to varying canal conditions.

The barrier targets bottom-dwelling fish, allowing fish that reside in the upper water column to pass. It is intended to deter the fish, not to stun or kill them. Thus far, laboratory tests at the Great Lakes Science Center have found electrical parameter settings that successfully repel about 80 percent of goby attempts to cross the barriers. Changes in water flow did not affect this success rate. Development and implementation of the goby barrier will represent significant progress toward ecosystem protection of the Great Lakes and Mississippi River basins.

Federal funding of $1.2 million from the U.S. Army Corps of Engineers and U.S. EPA is supporting the design and construction of the dispersal barrier. A combination of funding sources, including nonfederal contributions, will be required for continued operation and monitoring of the barrier. Construction of the benthic barrier is scheduled for August of 2000. Although the goby has already been sighted downstream from the barrier, it is hoped that the barrier will impede further spread of the goby and prevent the migration of other nonindigenous species. The barrier also will serve as a valuable demonstration project that can be used to address similar problems in other areas.

Detection and Monitoring

It is recognized that there is a general lack of detection and monitoring programs for nonindigenous invasive species for the Great Lakes region. The summaries in the following section are based on presentations from the *Great Lakes Nonindigenous Invasive Species Workshop, Chicago 1999* and are offered as guidance in the development of NIS detection and monitoring programs for the Great Lakes region).

<u>*A Paradigm to Guide the Development of Nonindigenous Species Detection and Monitoring Programs*</u>: (presented by Don Schloesser, U.S. Geological Survey (USGS)) Detection and monitoring of nonindigenous invasive species should be considered the foundation of prevention and control efforts. Presently, however, these programs do not hold a high profile in research paradigms for either terrestrial or aquatic nonindigenous species. Detection of a nonindigenous species refers to finding an organism in an environment outside its normal range where it was not previously present. Monitoring refers to keeping track of the species, both in terms of historical distribution and abundance. Integral to detection and monitoring efforts is *reporting* (an assessment and related publicity regarding the discovery of a new organism) and *evaluation* (an assessment of the potential impacts of new nonindigenous invasive species).

In formulating historical models for NIS detection, the focus is on species that are relatively new introductions and environmentally disruptive rather than those that are established and are not disruptive to the ecosystem. Species are generally detected in one of the following ways:

Random Event: Discoveries occur by chance, often by the general public. Random searches through museum collections could possibly double or triple species on the list.

Incidental Detection: Field scientists conduct an informal survey for nonindigenous species during the normal course of scientific study because of an awareness that new discoveries might occur. This awareness has increased in past decades, but is still probably less than five percent of total findings.

Active Pursuit: Field scientists actively search for nonindigenous species on a random basis, although rare due to cost. Exceptions include inspections of agricultural products and ballast water of ships.

Monitoring models depend on funding availability, nevertheless, the following usually characterizes monitoring efforts.

I. Individual taxonomic experts conduct monitoring on a case-by-case basis. This accounts for about 40 percent of past monitoring activities.
II. Individuals in agencies conduct monitoring on a case-by-case basis with “stolen” time from other projects. This accounts for about half of NIS discoveries.
III. Agency designated to track distribution, abundance and impacts of species conducts monitoring on a case-by-case or generic basis with allocated funding. There is active but fragmented organization between agencies in this model, which also relies on volunteer programs.

(Note that these models are only as flexible as funding and vested interests allow.)

Presently, a sound model for NIS detection and monitoring that facilitates early response and implementation of appropriate eradication/control measures does not exist. The current trend of combining Models I and II for both detection and monitoring will continue to provide the basis for NIS program development. Model III is not cost-effective.

A predictive approach to detection and monitoring, also under consideration, has led to the discoveries of *Cercopagis* and *Daphnia holtzi*. Application of predictive modeling could narrow the NIS target list, making it more feasible to identify specific monitoring locations. Another recommended component is the expansion of monitoring to include impacts to the ecosystem. According to the Congressional Research Service (September 15, 1999), there are no current laws that address the critical period between NIS detection and establishment of a new invasive species. At present, Greg Rouiz of the Smithsonian Institute is leading an initiative involving a standardized, ongoing approach to surveying ecosystems for nonindigenous invasive species that would address the lag time between detection and establishment of a species. Biodiversity is another recommended component of NIS detection and monitoring programs.

The following are recommendations to improve NIS detection and monitoring programs:
- Develop regional NIS lists on a watershed basis;
- Provide incentives for taxonomic experts to detect, report or evaluate nonindigenous species;
- Establish a detection and monitoring approach that is more proactive;
- Decrease the time between detection and reporting;
- Evaluate the ecological and economic impacts and control options more quickly;
- Develop quick response teams with objective membership;
- Integrate detection as part of NIS research;
- Predict future invaders to facilitate early detection and prompt action;
- Develop regulatory support to facilitate action when eradication is still possible;
- Establish an emergency funding source for eradication of new nonindigenous species.

Monitoring and Ecological Impacts: (presented by Tom Nalepa, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Lab) Nonindigenous invasive species have created an unstable ecosystem in the Great Lakes, making the prediction of systematic changes difficult. While ecological change has always been a component of the Great Lakes system, the changes seen over the past 10 years, particularly in nearshore regions, are unprecedented. Many of these ecological changes are unique to the Great Lakes and could not have been predicted. For example, the invasion of zebra mussels led to the two unexpected changes to the Great Lakes ecosystem: 1) blooms of blue-green algae in nearshore areas, and 2) declines in *Diporeia* in offshore regions.

Ecological uncertainty exists because NIS impacts occur at different time scales and are interactive by nature. Given the pervasive nature of current impacts, monitoring broad ecological change is essential to wise resource use. The fact that other species are poised to invade is of great relevance to ecological monitoring.

Diporeia in Lake Michigan is discussed as an example of an ecological response to invasive species with an uncertain outcome. Since 1992, numbers of *Diporeia* have declined both in portions of the lake where zebra mussels are abundant and in areas where zebra mussels are not found. Between 1998 and 1999, the decline appeared to accelerate, and evidence suggests that numbers now also are declining in the northern portion of the lake. Few *Diporeia* will be found in Lake Michigan within the next 10 years at the current rate of decline. As *Diporeia* is a major food source for many species of fish, its decline will certainly affect the feeding habits and, in turn, the distribution and population size of fish. Preliminary evidence suggests that these impacts are already occurring.
The following recommendations are provided based on this ecosystemic research of *Diporeia* decline:
- Monitoring partnerships need to be formed to examine as many biological components as

possible because the overall impact to the ecosystem is unknown.

- Integrating experimental studies with monitoring activities should be a high priority.
- Consideration must be given to links between the upper and lower ends of the food web.

<u>*Detection and Monitoring of Plant Invasions*</u>*:* (presented by Noel B. Pavlovic, USGS, Biological Resources Division) Nonindigenous plants undergo four stages of colonization and invasion:

- **Lag phase**: repeated introduction of species where some species succeed and others do not over time;
- **Permanent established phase**: organisms have become permanently established and are reproducing, but their populations are still relatively small;
- **Colonization**: populations begin to disperse to and invade new areas;
- **Infiltration**: species penetrate disturbed ecosystems.

Monitoring initiatives should be designed so detection occurs early in the invasion process when control and eradication are still possible. This is a rare event, however, since detection is difficult. The standard result of detection is, at best, containment. Monitoring for organisms needs to be multiphased involving detection of rare events coupled with controlling large populations. The vigilance of resource managers and the public is the best means for early detection.

National parks traditionally do not inventory native plants and animals, and awareness of NIS populations on their lands is limited. In addition, there is a need for a quantitative monitoring and ranking system for invasive plants to protect the parks' repositories of native biological species. The detection of new invasions is difficult and often haphazard. Chronic disturbance in terrestrial systems, such as roadside habitats and other areas, has been shown to make plant communities more vulnerable to NIS invasions. Community vulnerability, particularly in natural areas of national parks, should be integrated into detection and monitoring programs.

Research scientists from USGS are involved in a project to monitor invasive plants in national parks and lakeshores of the Great Lakes region, studying the effect of increased invasive plant populations on the biodiversity of native populations. The study uses a two-phased approach to sampling and compares the presence of invasive species between parks, among communities within parks and compares different ecological disturbance regimes (measured by logging and cultural impacts). This system for monitoring generates baseline data and identifies common nonindigenous species in an invasive plant ranking system developed by the National Park Service and USGS.

Finally, there is a significant role for communication regarding the control of invasive plants. For example, communication with and among park staff and other natural area managers may provide NIS information that can facilitate the early detection and eradication of new invasive species. All levels of government must be involved to effectively control invasive plants in areas of chronic human disturbance. Most importantly, there is a need to detect nonindigenous plants in early phases of infestation to facilitate containment and eradication. Dissemination of information to land managers, followed by vigilant quantitative and qualitative monitoring and aggressive control measures, are the means to effectively control invasive species at the early stages of invasion. These approaches are not a panacea to preventing NIS problems, but they can go a long way toward decelerating their spread.

<u>*Importance of Accurate Inventory Data and Information Sharing for Implementing Effective Invasive Plant Control Programs*</u>: (presented by Miles Falck, Wildlife Biologist, Great Lakes Indian Fish and Wildlife Commission) Purple loosestrife (*Lythrum salicaria*), a perennial plant native to Europe and

Asia, readily invades North American wetlands and wet meadows to the detriment of native plant communities. The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) has been conducting active control of purple loosestrife in northern Wisconsin since 1988. Because specific control options vary depending on local site characteristics, an accurate, updated inventory of loosestrife locations, coupled with measures of relevant site attributes, is an integral tool for planning annual control efforts. The inventory component is used in conjunction with other program management tools, including education, control and evaluation.

Annual distribution surveys target specific landscape features predisposed to loosestrife invasion, such as roadside ditches and boat launches. Submissions from the general public through postcards or an interactive web site supplement the data. Distribution data and management actions are compiled in a GIS database and available at www.glifwc.org.

Accurate inventory data provides the basis for prioritization, coordination and identification of gaps in active control measures. The data are compiled on a watershed basis, providing boundaries for management efforts. Knowledge of the plant's ecological requirements and dispersal vectors enables identification of source populations, dispersal routes and threatened habitats when relevant data themes are overlaid with the inventory data. Prioritization, based on the data provided in the inventory, is an important element in management decisions.

An accurate map depicting land ownership provides an effective tool for coordinating efforts among cooperators by identifying owners of untreated populations and identifying populations that may have restricted management options. This information provides the basis for an effective information/education program for purple loosestrife control among private landowners, as well as agency personnel. In addition, periodic updates and control histories for each site allow for evaluation of management actions taken. Although unique to purple loosestrife and its specific ecological requirements, this model may be readily adapted to fit the life histories of other invasive plant species and aid in their management.

It is important to note the following assumptions made in the course of this discussion:

- Purple loosestrife is merely one of many invasive plant species in the upper Great Lakes region.
- Limited resources suggest that only a few of the worst invasive plants in the early stages of infestation may be successfully managed.
- No single agency can be expected to accomplish this task on its own.

Based on the work conducted thus far, the following recommendations are offered:

- Baseline data on the distribution, ecology and relative threats posed need to be gathered or compiled for other invasive plants in the region.
- Data should be applied in developing criteria to evaluate which invasive plant species should be targeted for control (based on species impacts) and where conservation and/or restoration efforts should be focused.
- Survey and monitoring methods and data formats should be standardized as much as possible to facilitate information sharing.
- Coordination and information sharing are of critical importance to avoid duplication of effort and wasting of valuable resources.
- Data should be readily accessible, preferably utilizing Internet technology, to facilitate efficient coordination among cooperating agencies and individuals.

Education/Outreach: Raising Public Awareness

An informed and educated public is widely recognized as the cornerstone of an effective NIS prevention and control program. To achieve this end, it is essential that information and education (I/E) efforts convey accurate facts that are appropriately targeted and offer a consistent message from one jurisdiction to the next.

Great Lakes Panel on Aquatic Nuisance Species: The directive under Section 1203 of NANPCA (refer to the section on Great Lakes Panel), has provided the basis for the Panel's work on its I/E program with the overall focus of enhancing awareness and understanding of ANS issues, associated ecological and economic problems, and technically and economically feasible techniques designed to mitigate these problems.

The first major step taken by the Great Lakes Panel on I/E programming was the development in 1993 of the *Information/ Education Strategy for Aquatic Nuisance Prevention and Control* (see Great Lakes Panel 1996(b)). The purpose of the strategy is to coordinate activities conducted by Panel members, build regional partnerships that will increase the effectiveness of information and education activities, and most importantly, support the development and dissemination of consistent messages regarding ANS prevention and control (see Figure 9). An updated version of the I/E strategy is underway as of spring 2000 to reflect new ANS programs, the expanding role of coordination, new species introductions, emerging complexities of control efforts and challenges of implementation.

Figure 9. Diverse Audience of the Great Lakes Panel's I/E Program

- water user groups holding potential for ANS introduction and spread such as commercial shippers, recreational boaters and anglers
- municipal and industrial water users who must deal with the high costs of mitigating ANS impacts
- resource managers in both state and federal agencies who are faced with the challenges of implementing strategies for ANS prevention and control
- state and federal policymakers responsible for the promotion of ANS legislation and appropriation of funds

Source: Great Lakes Panel on Aquatic Nuisance Species 1996.

The need for enhanced coordination among various stakeholders with regard to I/E products and activities was recognized as a priority by the Great Lakes Panel and resulted in the 1996 document, *Aquatic Nuisance Species Information and Education Materials Relevant to the Great Lakes Basin: Recommendations and Descriptive Inventory.* The inventory, produced for use by the public agency staff, researchers, elected officials and other parties, is a comprehensive guide to informational materials available on aquatic nuisance species in the Great Lakes region (Great Lakes Panel 1996(b)).

The I/E materials in the inventory are listed by primary topic and cross referenced by source, secondary topic and geographic coverage. The primary topics covered in the inventory are categorized in Figure 10. Within each topic, the products are listed by format (e.g., fact sheet, report). Each product listing includes the following information: reference number, title, source (agency name, address, phone, fax and e-mail), topic(s), date, length, cost, target audience(s), geographic coverage and description.

Figure 10. Primary Topics Included in Great Lakes Panel Inventory

- Species of Concern
  - zebra mussel
  - purple loosestrife
  - Eurasian watermilfoil
  - sea lamprey
  - Eurasian ruffe
  - round goby
  - spiny water flea
- General ANS
  products addressing two or more species or ANS issue in general
- Other Nuisance Species
  - water chestnut
  - rudd
  - rusty crayfish
  - alewife
- Policies and Regulations
- Ballast Water

Source: Great Lakes Panel on Aquatic Nuisance Species 1996.

As part of the document, the Great Lakes Panel approved the following recommendations:

- **Development and Use of Internet-Based Resources on Aquatic Nuisance Species**: Electronic communications technology has proven to be a highly successful and efficient means of publicizing and distributing information on aquatic nuisance species. The ANS community has been well served, among others, by the Internet-based Great Lakes Information Network (GLIN), operated by the Great Lakes Commission, and the Sea Grant Nonindigenous Species (SGNIS) web site, operated by the Great Lakes Sea Grant Network. Every effort should be made to exploit the full potential of such technology for the benefit of students, educators, representatives from government agencies, researchers, consultants, and industry and business who are involved in and/or affected by ANS prevention and control efforts.
- **Marketing and Distribution of I/E Resources and Activities**: An array of I/E materials on aquatic nuisance species is presently available and development of additional materials is an ongoing process. To ensure that such materials and associated activities are of greatest possible benefit to target audiences, they must be easily accessible, broadly distributed and actively provided. Towards that end, a marketing strategy for each I/E product and activity should be identified and implemented by the Great Lakes Panel and other appropriate partners.
- **Coordinating I/E Efforts**: Successful prevention and control efforts are fundamentally dependent upon I/E programs that are comprehensive, carefully targeted and offer a consistent message from one audience to the next. Given limited resources and the magnitude of the task, cooperation and coordination among the many information providers must be extensive. Efficiency and cost-effectiveness in the collective effort is essential.
- **Outreach to User Groups and Other Stakeholders**: Preventing and controlling the spread of aquatic nuisance species is the individual and collective responsibility of relevant public agencies,

business and industry, a range of resource user groups and the public. Each of these entities must initially be considered a target audience for I/E programs and eventually a vehicle (and partner) in reaching larger sectors of the Great Lakes citizenry.

Further details on the Great Lakes Panel's recommendations on I/E programming, including the aforementioned *Information/Education Strategy* can be found in the document, *Aquatic Nuisance Species Information and Education Materials Relevant to the Great Lakes Basin: Recommendations and Descriptive Inventory*, which is available on the Great Lakes Information Network's web site at: http://www.glc.org/projects/ans/ans-ie/httoc.html.

<u>National Sea Grant College Program</u>: From sponsoring research to conducting public education programs, Sea Grant has focused on finding active solutions to the invasions of nonindigenous aquatic nuisance species. Sea Grant is the primary source of information on a range of aquatic nuisance species such as the zebra mussel, Eurasian ruffe, round goby, green crab, purple loosestrife, *Phragmites* and others. The Sea Grant network houses technical collections and provides the public with easy access to online information. Researchers, extension specialist and educators continue to share their expertise at international research conferences, training workshops and video conferences, many of which are sponsored by Sea Grant programs. A new three-year initiative also will bring research and outreach efforts to inland states. The following describes important Sea Grant initiatives to advance ANS prevention and control in the Great Lakes region and across the country.

- The National Aquatic Nuisance Species Clearinghouse is an extensive technical library of publications related to the spread, biology, impacts and control of the zebra mussel. The clearinghouse also includes smaller libraries addressing the Eurasian ruffe, round goby, tube-nosed goby, spiny water flea and more. Started by New York Sea Grant in August 1990 as the Zebra Mussel Information Clearinghouse, its mission was expanded in 1997 to include other freshwater nonindigenous aquatic nuisance species. This mission was again expanded in October 1998 to include important marine aquatic nuisance species. The mission of the clearinghouse is to: 1) facilitate and coordinate sharing of ANS information among all levels of university, government, and private industry researchers throughout North America; 2) provide continuity to the timely dissemination of findings of zebra mussel and other ANS research; 3) facilitate technology transfer between zebra mussel and ANS researchers and end user audiences; 4) focus attention on the need for additional research and outreach to enhance the fight against zebra mussels and other aquatic nuisance species; and 5) provide a convenient means of access to the clearinghouse's extensive technical libraries via the Internet.

- The Sea Grant Nonindigenous Species Site (SGNIS), is an online interactive national information center produced by the Great Lakes Sea Grant Network. This web site (http://www.sgnis.org) contains a comprehensive collection of research publications and education materials produced by Sea Grant programs and other research institutions on aquatic nuisance species. All materials available through this site have either appeared in professional science journals or have been through a rigorous scientific review to ensure the quality of the information provided. Links are provided to other sites that also focus on nonindigenous species.

- The Nationwide Zebra Mussel Training Initiative is a program led by New York Sea Grant and Minnesota Sea Grant. It provides for the identification, preparation and dissemination of educational materials for audiences directly affected by the invasion of the zebra mussel or in a position to develop and implement policy for ANS prevention, control and mitigation of related impacts. Goals of the training initiative are as follows: 1) delay the spread of zebra mussels into new watersheds, 2) help uninfested regions prepare for the arrival of zebra mussels, and 3) mitigate zebra mussel impacts upon arrival. The initiative was designed to create a mechanism through which Sea Grant could assist state resource managers, educators and resource users in establishing programs to address the inland spread of zebra mussels. Program efforts were also made to foster interagency cooperation and participation in state or regional zebra mussel task forces. Under the auspices of the training initiative, two day-long satellite teleconferences have been held along with fifteen regional workshops in locations across the country. Groups participating in these events included surface water infrastructure, resource management and environmental regulatory agencies, public officials, environmental interest groups, lake associations and the media.

- The Exotic Aquatics and Zebra Mussel Mania traveling trunks are educational outreach products produced by Minnesota Sea Grant and Illinois-Indiana Sea Grant. The products provide curricula to teach youth about nonindigenous species and the effect the health of the Great Lakes and inland waterways. The traveling trunks are comprised of hands-on activities, including museum-quality preserved ANS specimens, models of native clams, books, maps, posters, magnifying glasses, experiments, games, stories, and activities and lessons which meet science education standards. Students can inquire and discover while learning how to become involved in community action projects to help slow the spread of zebra mussels.

- The Citizen Monitoring Program, led by Michigan Sea Grant (MSG), provides a forum for citizen volunteers to collect zebra mussel data from inland lakes using equipment and instructional materials developed on the campus of Michigan State University (MSU). Using MSG's zebra mussel veliger monitoring kit, citizens have provided an estimated 2,000 hours of field monitoring and data that contribute to the understanding of the zebra mussel invasion. The state's 350 lakefront property owner associations, important MSG partners in developing the monitoring program, frequently use the equipment, as do teachers and nature centers. Sea Grant coordinates the long-term equipment loan programs, collects and verifies sampling data, and publishes results, which receive widespread media attention. The straightforward, low-cost program demonstrates the efficacy of volunteer efforts in gathering scientifically useful water quality data, while tracking the spread of zebra mussels. Perhaps most importantly, the program engages property owners in lake resources management; this participation is critical in coping with ANS invaders. When a zebra mussel infestation is discovered, citizen leaders disseminate information around the lake, post signs and hold workshops to help prevent the spread to other lakes. Today, the monitoring materials are being used as a model by Sea Grant programs from as far away as Washington and Florida.

- The Purple Loosestrife Project, another MSG outreach project, engages citizens and young adults in the control of purple loosestrife using the plant's own natural enemies. The hardy wetland plant has become part of the Michigan landscape and has replaced native wetland plants in many locations, along with the animals that depend on them. Long-standing control practices such as burning and herbicide application have failed. MSG, in partnership with the MSU Department of Entomology, have created the Purple Loosestrife Project, which is aimed at reducing the plant's numbers by integrating citizen stewardship education with biological control.

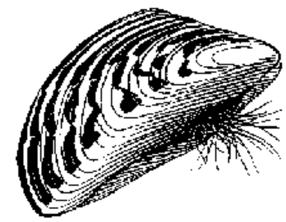
  The project began with a unique loosestrife locator postcard survey that engaged citizens in identifying nearly 500 of the largest wetland infestations in Michigan. Hundreds of teachers, students, naturalists, property owners and citizen groups now participate in the project, helping to restore Michigan's biodiversity and natural wetland function while learning the key concepts of biological control. Since the Purple Loosestrife Project began in 1997, volunteers have raised and released *Galerucella* leaf-feeding beetles (one of the plant's natural enemies in Europe) across Michigan. The beetles are establishing populations in stands of purple loosestrife and are beginning to cause significant defoliation. In addition, MSG assisted teachers in producing a *Cooperators Handbook*, which features 25 outdoor learning activities and classroom experiments and serves as a comprehensive guide to purple loosestrife biological control.

- The Exotic Species Day Camp for Educators is a project of the Great Lakes Sea Grant Network. It has provided support to an estimated 18,000 students in making sound decisions in regard to their actions involving spread and transport of nonindigenous aquatic nuisance species. Educational workshops were conducted with 125 classroom teachers and environmental educators in seven states. They participated in hands-on training that featured Sea Grant's traveling trunks (Zebra Mussel Mania and Exotic Aquatics); surfing SGNIS, using Solution Seeker CD-ROM; trying out the Zebra Mussel Citizen Monitoring Kit; doing activities from *Great Lakes Instructional Materials for the Changing Earth System* and from the Purple Loosestrife Project; and viewing *Mussel Menace: Zebra Mussels and You*, an instructor's training package.

  Coordinated by Illinois-Indiana Sea Grant in partnership with Sea Grant programs in Michigan, Minnesota, New York, Ohio and Wisconsin, this project reached its goal to broaden distribution of ANS education to teachers, students, environmental educators and outdoor education center visitors in the Great Lakes region. In spring 2000 a new collection of teacher-developed activities will be available for educators throughout the country. The "ESCAPE" collection will offer 33 hands-on activities exploring the many facets of nonindigenous aquatic nuisance species in a framework that integrates science with math, language arts, social studies and the cultural arts.

Case Studies on Nonindigenous Invasive Species: Significant Threats to the Ecosystem Health of the Great Lakes Basin

Zebra Mussel *(Dreissena polymorpha)*



The zebra mussel is one of the premier aquatic invaders of the Great Lakes, where colonization has fouled intake pipes, navigation locks and other pieces of aquatic infrastructure. Originally from the Caspian Sea region, the zebra mussel spread throughout much of Europe before the Industrial Revolution and the development of the continent's infrastructure. While European infrastructure was able to adapt to the zebra mussel infestation with intakes, sand filters and other features that help reduce fouling, North American waterworks were not designed with zebra mussel infestations in mind (Bright 1998).

Although not officially discovered in Lake St. Clair until 1988, the zebra mussel is believed to have entered the Great Lakes in 1985 or 1986 through ballast water discharge. Zebra mussels spread throughout the lakes rapidly. By1989, they had colonized Lake Erie; four years later, zebra mussels could be found in all of the Great Lakes. Moreover, several inland lakes, including Balsam Lake in Ontario and Kentucky Lake in Kentucky, have reported infestations of zebra mussels. The infestation of zebra mussels has spread farther, and faster than was expected when the first sightings were reported (Ohio Sea Grant 1996).

The rapid spread of the mussels can be attributed to several factors. Zebra mussels have extremely fertile reproductive cycles, with a mature female producing up to one million eggs per season. While it is estimated that only 1 to 3 percent of these eggs mature into adulthood, those that do survive live to approximately three years of age. Additionally, zebra mussel colonies are durable, demonstrating little sensitivity for light intensity, hydrostatic pressure (depth), or temperature (as long as it is within a normal environmental range) (Ohio Sea Grant 1996).

Their endurance heightens the ecological disruptions caused by zebra mussels. Adults are capable of filtering one or more liters of water per day, removing phytoplankton and some forms of zooplankton, thus giving the water a crystalline clarity. Removing these elements eliminates a major food source for zooplankton, which can impact the food chain, potentially reducing fish populations. Research has already been conducted examining the effect of zebra mussels on fathead minnow larvae, yellow perch, and benthic macroinvertebrate populations in the Great Lakes. For instance, data collected by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory suggests that lower food availability resulting from the introduction and rapid spread of the zebra mussel is having an adverse impact on the population of the amphipod *Diporeia.* This macroinvertebrate is a component in the diet of most species of fish during at least some stage of their life cycle, including yellow perch, bloater, alewife and sculpin, which serve as prey for the larger piscivores such as trout and salmon (Nalepa 1998). It also has been observed that in Lake Erie, the value of catch dropped from $600 million before the invasion to $200 million by early 1990s (Ohio Sea Grant 1996).

Furthermore, some researchers hypothesize that, while zebra mussels might be causing detrimental effects to certain beneficial phytoplankton, they also might be promoting the spread of other plants, such as *Microcystis*, a nuisance bloom of blue-green algae. Zebra mussels do not readily choose to feed on

Microcystis. This selective feeding pattern could allow *Microcystis* to proliferate in the absence of its competitors. Enhancing the spread of *Microcystis* causes several ecological concerns. Not only is the algae a poor food source for zooplankton, but this nuisance algae also can be toxic to some organisms and may create taste and odor problems in water, such as those experienced throughout the summer of 1994 at Michigan's Saginaw-Bay City Water Intake (Vanderploeg 1995).

Zebra mussels also may have a potentially negative impact on certain cold-water spawning fish species like lake trout (*Savelinus namaycush*). When zebra mussels infest an area that is also a spawning reef for lake trout, colonization by the mussels may damage trout eggs. The mussels do so by blocking trout eggs from falling into areas where they would normally incubate during the winter, producing organic matter harmful to the eggs, or damaging the eggs through movement. A recent study in Lake Michigan suggests that zebra mussels negatively effect spawning since adult trout tended to avoid spawning in areas littered with zebra mussels. Moreover, zebra mussel populations cause damage to eggs as the mussels contact natural substrates (Marsden and Chotkowski 1998).

As far as the threat to native species, zebra mussels kill native mussels by encrusting their shells so heavily that the native species cannot open to feed or breathe. In the Mississippi River basin, 140 native mussels face extinction as zebra mussels continue to spread through the watershed (Bright 1998).

Finally, zebra mussels have been connected with contaminant cycling. The United States has long recognized the detrimental effects of toxic contaminants, such as polychlorinated biphenyls (PCBs), on human health. However, when a fish is found with high levels of PCBs, it is often difficult to determine the source of the contaminant. Recently, researchers have begun to focus their efforts on studying contaminant cycling through the food chain. Zebra mussels could be an important source of PCB redistribution because of their capacity to filter large amounts of water and their tendency to feed on contaminated sediment and algae. The PCBs present in zebra mussels may provide a source of contamination to the entire Great Lakes community, beginning with bottom-feeding fish, wildfowl, crayfish and other organisms that eat the zebra mussel or their excreta. Moving up the food chain, from algae to zebra mussels to commercial fish, PCBs are thought to biomagnify at each level. Researchers are currently attempting to determine the exact level of biomagnification in order to identify the level of risk to human consumers of the contaminated fish (Jentes 1999).

The zebra mussel inflicts a toll not only on the ecology of the Great Lakes, but also on the economic health of the region. The zebra mussel infestation has imposed large costs on facilities that draw water from the Great Lakes, such as electric generating plants, municipal water systems and industrial water users. While zebra mussels can easily plug small water intake sources completely, even large water systems are at risk. Detroit Edison's power plant in Monroe, Mich. the largest fossil fueled plant in the world, was forced to shut down in 1989 due to a clogged water system caused by zebra mussels. The cost of mussel control accumulates quickly when factoring in downtime, retrofitting, chemical applications (e.g. chlorine), scraping them out of pipes or blasting them out with high-pressure hoses (refer to sections on economic impacts).

In the Great Lakes region, documented cumulative losses between 1989 to1994 to major users of untreated surface water exceeded $120 million (Hushak 1996). Power plants are extremely vulnerable to the economic impacts of zebra mussels due to the high volume of water used. The total economic impact incurred on the electric generation industry has been estimated at $35.3 million. Nuclear plants that use water for cooling as a safety measure are particularly at risk. At least 12 North American nuclear plants are infested by mussels with control costs averaging $825,000 per year. Predictions of the cumulative losses to all users, from individual boat owners to municipal water users, by the year 2000 range from $3.1 billion to $5 billion (Bright 1998).

Control of zebra mussels at a Great Lakes regional level is not yet considered possible. Several different control strategies have been attempted. A popular strategy is the use of chemical treatments such as chlorine, which has been used to limit zebra mussel populations. The problem with a chlorine treatment strategy, however, is the environmental side effects, including harm to other aquatic life forms and the production of carcinogenic organic by products. In some areas of the world, zebra mussel populations have been controlled by predation by diving ducks. While there is some evidence of this phenomenon occurring in Canada (Pt. Pelee, Western Lake Erie), this control strategy is limited only to warmer months when the Great Lakes are not frozen. Other potential control strategies include disruption of zebra mussel reproduction and a variety of different mechanized control methods (i.e., screening and electric fields).

Sea Lamprey *(Petromyzon marinus)*

The sea lamprey is a primitive, jawless fish native to the coastal regions of both sides of the Atlantic Ocean. Sometimes, compared to a "fish vampire," the predaceous, eel-like fish has a mouth that attaches itself to the body of a fish and sucks blood and tissue from the prey's wound with its rasping tongue. It preys on all species of large Great Lakes fish, including the lake trout, salmon, rainbow trout, whitefish, chubs, burbot, walleye and catfish.

Sea lampreys were first observed in Lake Ontario in the 1830s. They entered the Great Lakes through the Welland Canal around 1921. The lamprey was first observed in Lake Erie in 1921 and rapidly invaded the other Great Lakes, appearing in Lake St. Clair in 1934, Lake Michigan in 1936, Lake Huron in 1937 and Lake Superior in 1938. By the late 1940s, sea lamprey populations had exploded in all of the upper Great Lakes, contributing greatly to population declines of whitefish, lake trout, walleye and other critical fish species in the Great Lakes (Great Lakes Fishery Commission, Fact Sheet 3).

Through its ability to parasitize fish by feeding on body fluid, each lamprey, during its life, can kill more than 40 pounds of fish. This predatory behavior has had a devastating impact on the Great Lakes fishery. The sea lamprey was implicated in the collapse of lake trout, whitefish and chub populations in the Great Lakes during the 1940s and 1950s. Before the sea lamprey's spread, the United States and Canada harvested about 15 million pounds of lake trout in the upper Great Lakes every year. By the early 1960s, the catch was only about 300,000 pounds. In Lake Huron, the catch fell from 3.4 million in 1937 to almost nothing in 1947. The catch in Lake Michigan dropped from 5.5 million pounds in 1946 to 402 pounds by 1953. Lake Superior catch dropped from an average of 4.5 million pounds to 368,000 pounds in 1961. The health of the once thriving Great Lakes fisheries has been significantly impaired by the sea lamprey's invasion (Great Lakes Fishery Commission, Fact Sheet 3).

Since 1956, the governments of the United States and Canada, working jointly through the Great Lakes Fishery Commission, have implemented a sea lamprey control program to reduce the impacts of this harmful invader. After testing almost 6,000 compounds in the 1950s, the key to sea lamprey control was found to be larval application of the chemical TFM (3 trifluoromethyl-nitrophenol). The lampricide is highly toxic to the sea lamprey and less toxic to other aquatic plants, fish and wildlife. The impact on non-target species can be reduced by closely controlling the concentration of TFM applied with the timing of application during the lamprey spawning run. Research indicates that TFM does not bioaccumulate and it breaks down in a number of days. The compound is registered with the U.S. EPA and Agriculture Canada (Great Lakes Fishery Commission, Fact Sheet 4).

Research has indicated the lamprey is most vulnerable to chemical treatment during the larval stage of its life cycle. During this stage, which can range from three to 17 years, the larvae burrow into sand and silt of tributary streams. The larvae, which grow to about 6 inches, feed on bottom debris and algae carried to them by stream current. After the larval stage, the window of opportunity for chemical control closes as the sea lampreys transform into their parasitic phase and migrate into the open waters of the Great Lakes.

For this reason the Great Lakes tributaries, not the open waters of the lakes, are treated with the TFM lampricide. Larval assessments are conducted to determine what streams need to be treated, when they need to be treated, and the actual location and abundance of larvae. The chemical and physical conditions of the stream (e.g. rate of flow, temperature, pH, and alkalinity) are also monitored. The objective of these assessments is not to use more TFM than is necessary for effective larval control that is environmentally safe (Great Lakes Fishery Commission, Fact Sheet 4).

Other control mechanisms also are being applied to increase the technical and cost-effectiveness of the sea lamprey control program:

- Mechanical barriers are constructed on streams in strategic locations throughout the Great Lakes to prevent sea lampreys from spawning, while still allowing the passage of other fish species. Physical control of sea lamprey was implemented before use of the chemical lampricide, TFM. The barriers were not entirely effective in stopping sea lamprey, with casualties sometimes occurring among non-target fish. The use of mechanical barriers as implemented again in 1988 to reduce the extent of expensive lampricide treatments. The barriers also are associated with lamprey trapping facilities, thus allowing the removal of sea lampreys from the spawning population, assessment information, and the trapping of males for the experimental sterile-male-release technique (see below) (Great Lakes Fishery Commission, Fact Sheet 5).

- Sterile-male release technique, currently being conducted as a large-scale experimental program, involves trapping sea lampreys, which are then sterilized and released into the St. Marys River. It is conjectured that the sterilized males will compete as aggressively as normal males, wasting the spawning potential of the female sea lampreys. Sea lamprey traps are placed in strategic locations on Great Lakes tributaries, frequently as part of existing sea lamprey barriers, trapping 25,000 male sea lampreys annually. The trapped male lamprey receive a carefully measured dose of the sterilant, Basazir, and are marked with a fin clip. After a period of 48 hours, which allow the sterilant to clear from the lampreys' system, they are released in selected tributaries of Lake Superior and Lake Huron (Great Lakes Fishery Commission, Fact Sheet 6).

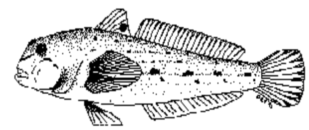
  Preliminary results of the sterile-male release experiment indicate that sterilized males effectively move into the spawning grounds with the rest of the population. The sterilization process does not diminish the male's drive to spawn. Preliminary assessment indicates that the number of viable nests and fertilized eggs has been reduced at expected rates. The next stage in the experiment is to determine if the fewer viable nests reduce the number of larval sea lampreys. If the number of larval lampreys can be reduced by the sterile-male-release technique, this biological control approach will be an integral part of the sea lamprey control program (Great Lakes Fishery Commission, Fact Sheet 6).

- Bayluscide spot treatments are used to kill concentrated populations of lamprey larvae on the river bottom. These areas of high larval concentrations are detected with the use of global positioning technology.

The cost of the sea lamprey research and control program is undoubtedly expensive, estimated at $10 million annually by the Office of Technology Assessment report of 1992. However, this cost is nominal when compared to the risk posed to the Great Lakes fishery, valued at $500 million annually, in the absence of sea lamprey control (Dettmers 1998).

Round Goby *(Neogobious melanostomus)*

The round goby was first discovered in the St. Clair River in 1990 (Jude et al. 1992). The round goby's arrival to the Great Lakes drew little attention since primary concern at the time was focused on zebra mussels. Three years later, the goby still remained within a few miles of its point of introduction. Confinement or elimination of this invader while still geographically limited did not occur. In late 1993, the round goby began to expand its range, and by 1995, it had spread to all five Great Lakes where it has become established as a permanent part of the ecosystem. As of June 2000, verified migration of the goby extended into the Calumet River, through the Calumet Sag Channel, and south into the Des Plaines River as far down as Joliet, about 50 miles southwest of Chicago (Thiel pers. comm. June 2000). Once it enters the Illinois River drainage, the round goby will have access to almost half of the United States through connecting waterways (Marsden 1996).



Hailing from the Black and Caspian Seas, the same area of the world as the zebra mussel, the round goby has rapidly dispersed to all five of the Great Lakes likely as a result of multiple invasions through ballast water transfer from Europe. A small, benthic, soft-bodied fish, it has been labeled as an example of the "perfect" invader for a number of reasons. The goby is a very aggressive, territorial and robust fish that is that is competitive for food, shelter and spawning areas. Contributing to the goby's competitive edge is its tolerance to a wide range of environmental conditions, high fecundity, a well-developed lateral line system allowing night feeding, and a large body size (up to 10 inches) compared with other benthic species (Manz 1998).

The goby disrupts the native ecological system by consuming the eggs and fry of native fish, such as sculpins, darters and logperch (Manz 1998). These impacts have already been observed on sculpin populations in areas where gobies have become established. In laboratory experiments, round gobies have been observed feeding on the eggs and fry of lake trout. Given the limited reproduction of lake trout in the Great Lakes, this type of predation could be very damaging to the basin's ecology (Marsden et al. 1998).

An interesting twist on the ecological impacts of the round goby is the fact that it eats large quantities of zebra mussels. Although a primary component of the goby diet, it is unlikely that the goby can significantly reduce the number of zebra mussels present in the Great Lakes. However, the use of zebra mussels in their diet is believed to give the goby a competitive advantage by providing a food supply that most native fish do not utilize. Consumption of zebra mussels by the round goby may contribute to problems of bioaccumulation of contaminants such as PCBs (refer to case study on the zebra mussel).

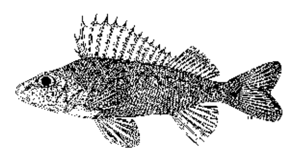
Existing mechanisms for the prevention and control of the round goby include ballast water management, public education efforts and river barrier systems. Ballast water exchange (refer to section on ballast water management) targets the goby's primary avenue of entry into the Great Lakes as well as many other nonindigenous species. This approach, however, can only reduce the introduction of more round gobies, not decrease established populations. Since the round goby is already established in the Great Lakes, controlling the expansion of its range is crucial.

Public education efforts and river barrier systems are two methods that resource managers are using to control the range expansion of the round goby. Public education efforts focus on the identification, current distribution and potential spread, biological and ecological characteristics, impacts, and protocol to stop its spread, including a nonindigenous species reporting form. Current products that disseminate this information include identification cards ("round goby watch cards"); fact sheets; web sites (including databases), and a graphics library; and informational presentations that are targeted to the appropriate water user groups (Charlebois et al. 1998). Additionally, Sea Grant offices in Great Lakes states and the U.S. Fish and Wildlife Service maintain up-to-date information on sitings and areas infested with round gobies available on their web sites and directly through their offices.

To control the downstream spread of the round goby into the Illinois River system, the U.S. Army Corps of Engineers is designing a barrier consisting of an electric field (see section on ANS dispersal barrier for more details). The barrier will consist of two pulsed direct current arrays, each extending across the canal and located approximately 300 meters apart. Each array will generate an electrical field effective to a height about 2 meters above the canal bottom, posing no threat to human safety. The barrier will be attached to the bottom and recessed into the sides of the canal so that barge traffic can continue to operate normally. The electric field can be modified to adapt to varying canal conditions. The barrier under design targets bottom-dwelling fish, allowing fish that reside in the upper water column to pass. It is intended to deter the fish, not to stun or kill them. Development and implementation of the goby barrier will represent significant progress toward ecosystem protection of the Great Lakes and Mississippi River basins.

Eurasian Ruffe (*Gymnocephalus cernuus*)

The Eurasian ruffe (*Gymnocephalus cernuus*) as its name suggests is a native of Eurasia and was first found in the Great Lakes in 1986 in Duluth Harbor, Minn. (Picard 1995). It was discovered during a local fish survey and is thought to have been transported to the area via ballast water (McLean 1993). Between 1986 and 1993, the ruffe increased its population 100 fold in the St. Louis River to comprise 80 percent of total fish abundance collected in trawls. It has since spread into Thunder Bay, Ontario; the Ontonagon River; many tributaries of Lake Superior, including the Sand, Flag, Iron, Amnicon, and Brule rivers; and Thunder Bay, Mich., in Lake Huron (McLean, Jensen 1996).



As an invasive species, many of the ruffe's characteristics cause concern. Among these are its ability to rapidly reproduce with females living an average of seven years, laying as many as 13,000 to 200,000 eggs per season. Males tend to live roughly three to five years with seven being the longest (McLean, Jensen 1996). The ruffe has also been described as being both aggressive and an opportunistic feeder. It is known to actively compete with sport and forage fish, such as its relative and Great Lakes native the yellow perch for nesting and feeding sites (Picard 1995) (Kindt, Busiahn 1994). To compete successfully, the ruffe relies on sensory organs called neuromasts, which lie in its head and lateral lines. These organs provide protection for the ruffe by detecting vibrations from predator and prey in the dark bottoms of the lakes that this bottom dwelling species prefers (McLean, Jensen 1996). Another advantage the ruffe has is that its diet is variable. It focuses mainly on benthic insects but is also known to feed on the eggs of other species, such as whitefish (McLean, Jensen 1996) (McLean 1993).

In a study done by the University of Minnesota Sea Grant, the ruffe was found to be more of a temperature generalist when compared to yellow perch. Because of their similarities, the ruffe directly competes with yellow perch for habitat resources. This study demonstrated that ruffe is able to thrive in slightly cooler waters (17°C), whereas the yellow perch functions better at 23°C. The ruffe is thus able to grow longer into the winter months and begin its growth earlier in the spring. To make matters worse, not only does this extra growth require a longer period of food intake, but the ruffe is also less efficient at using its food than the yellow perch, requiring it to eat even more. This extra foraging leaves a much greater dent in local ecosystem structure than would naturally occur (Minnesota Sea Grant). These alterations have been linked to population declines in yellow perch, trout perch, walleye (which feeds on perch) and emerald shiner. With ruffe sizes of only four to six inches the ruffe does little to help make up for the commercial, recreational and ecological value lost from these other species (Kindt, Busiahn 1994).

Management for the ruffe began in 1991 with the creation of a special Ruffe Task Force by the Great Lakes Fishery Commission. In 1992 the national Aquatic Nuisance Species Task Force determined that the ruffe was an aquatic nuisance species according to law and appointed members to a Ruffe Control Committee. The Committee then worked on the management plan that had been developed by the Ruffe Task Force and attempted to develop a plan that would confine the ruffe to the western side of Lake Superior. However, in August 1995, two months after the Committee submitted its plan to the ANS Task Force, ruffe were found in Lake Huron in Thunder Bay, Mich., and revisions had to be made to the plan. Eight components comprise the management plan: population reduction, ballast water management, population investigation, surveillance, fish community management, education and bait fish management (Ruffe Control Committee 1996). In September 1999 an evaluation of the plan found mixed results. Population reduction appeared poor, as did ballast water management outside of Lake Superior. However, surveillance, education and bait fish management received good scores with helpful educational materials such as brochures, pamphlets and wallet-sized id cards. Additionally, although populations in the smaller less managed waters had increased since the plan's implementation, no spread from its 1995 location was observed (Busiahn 1999).

Most of the management for the prevention of ruffe spread has been done through a voluntary ballast water management plan implemented in 1993 by the Great Lakes shipping industry. This plan states not to take on ballast water from ruffe inhabited waters between May and June, when fish may be small enough to pass through filters. If water must be taken in these areas, that water must be exchanged at a depth of at least 240 feet in Lake Superior west of a demarcation line between Ontonagon, Mich., and Grand Portage, Minn. (McLean, Jensen 1996). The shipping industry has been proactive in this form of ruffe control. This is based on the reasoning that the St. Mary's River would provide access to all other Great Lakes, making control efforts virtually impossible. However, research continues to investigate ways to prevent the ruffe's spread outside of Lake Superior through ballast water, including using heat, electrical charges, gas, sound, pulverization, carbonation, alteration after intake, obtaining water at different water levels, ultrasonic treatments, filters and increased saline content (Glassner-Shwayder 1995) (Picard 1995).

The ruffe's potential range is thought to extend from the Great Plains to the East Coast and into Canada, based on the similar conditions required for perch (Kindt, Jensen 1994). With this potential spread and eradication presumed impossible, research needs to continue on this invasive species' life history, its economic and ecosystem impacts, and ballast water and biological control options (Ruffe Control Committee 1996). Proper management of the health of native communities in this range will also be vital to suppressing an explosion of the ruffe's population. In addition, information will need to be shared and communication fostered between all interested parties to provide for common management practices and the most effective control possible.

Asian Longhorned Beetle *(Anoplophora glabripennis)*

(This section is based on the article, *The Asian Longhorned Beetle Infestation Moves West*, submitted by Stacey Carter-Lane, public affairs specialist, USDA-APHIS)


Drawing courtesy of USDA Forest Service, Northeast

In August 1996, a man in the Greenpoint neighborhood of Brooklyn, N.Y., noticed several perfectly shaped round holes in his maple trees. Seeing sawdust near the base of the trees, he thought pranksters had drilled the holes. He called a city inspector who determined the holes were drilled by an even worse offender, the Asian longhorned beetle. The Asian longhorned beetle, an attractive, but devastating non- native pest, kills trees by boring holes deep into them. The Brooklyn find was the first reported infestation in the United States.

Within weeks of the Brooklyn discovery, another infestation was found on Long Island in Amityville, N.Y. Surveyors from the USDA and New York State combed both neighborhoods. Quarantine areas were established to prevent infested wood from being moved. In Brooklyn alone, more than 1,400 beetle-infested trees have been felled. More than 1,600 trees not known to be hosts of the beetle have been planted to replace them.

While the fight continued in New York, a nightmare for tree-lovers and beetle-battlers unfolded 800 miles away. In July 1998, a man picked up timber from the Ravenswood neighborhood of Chicago, Illinois. Several days later, while unloading his truck, the man saw a black and white beetle on his mirror. Curious, he typed a description of the unusual bug onto the Internet and found a pest alert for the Asian longhorned beetle. He quickly called USDA.

Hundreds of trees in Ravenswood were found to be infested, along with trees in two nearby areas: Addison, in DuPage County to the west, and Summit, south of Chicago. Because there is no way to save an infested tree, nearly 500 trees in the Chicago area have been felled, chipped and burned. These trees, like those in New York, are also being replaced. The most recent infestation of the Asian longhorned beetle was discovered in February 1999 in the Bayside section of Queens, N.Y.

The USDA believes the Asian longhorned beetle was imported from China in untreated wood often used for pallets or packing material. On Dec. 17, 1998, the USDA implemented an interim rule requiring that all solid wood packing material from China and Hong Kong be heat treated, fumigated or treated with preservatives before arrival in the United States. During March 1999 alone, the USDA reported overall compliance with the interim rule to be 99 percent.

The Asian longhorned beetle is a pest of hardwood trees in its native China. There, the beetle has some natural enemies; in the United States, natural enemies have not yet been identified. The beetle attacks many different hardwood trees, including boxelder; Norway, sugar, silver and red maple; horsechestnut; poplar; willow; elm; mulberry; green ash; and black locust. Tree species not known to be hosts of the

Asian longhorned beetle include: ginkgo, honeylocust, Kentucky coffeetree, goldenraintree, sweetgum, redwood, Tupelo, redmond linden and silver linden.

The beetles spread quickly when they invade an area with hardwood trees. Typically, they attack a single tree at first, eating until they exhaust it as a food source. They then spread to nearby trees. Under its own power, this beetle can fly hundreds of feet. People can unintentionally spread the beetle by cutting or trimming an infested tree and moving the wood elsewhere.

Adult beetles are usually present from May to October, but can be found earlier in spring or later in fall if temperatures are warm. Adults often stay on the trees from which they emerged, or they may disperse short distances to a new host to feed and reproduce. Each female is capable of laying 30 to 70 eggs. The eggs hatch in 10-15 days and the larvae tunnel under the bark and into the wood where they undergo changes and develop into pupae. When their body structures have matured and hardened, the adults emerge from the pupation sites by boring a tunnel in the wood and creating a round exit hole, a bit smaller than the size of a dime.

The Asian longhorned beetle has the potential to damage such industries as lumber, maple syrup, fruit, and fall foliage tourism, which generate combined annual revenues of $138 billion.

Because the insects spend all but the summer months inside the tree, they are virtually impossible to eradicate them with insecticides. Research has yet to produce a trap specific to this pest. Currently, the only way to eradicate the beetle is to remove and destroy infested trees. The best way to fight this insect, and similar non-native wood borers, is to prevent such pests from entering the country. At present, Plant Protection and Quarantine officers from USDA-APHIS conduct increased visual inspections on high-risk cargoes and in high-risk areas, such as cargo distribution warehouses.

In March 1999, Agriculture Secretary Dan Glickman signed a declaration of emergency. The declaration entails transferring $5.5 million in new funds to assist in detecting the Asian longhorned beetle, identifying infested areas, controlling and preventing the spread of the beetle to non-infested areas, and eradicating the pest.

Early infestation detection and rapid response to treatment are crucial to successful eradication of the beetle. What can people do to help protect American trees from this devastating pest? Know the signs of the Asian longhorned beetle. Asian longhorned beetles are big, showy insects. They are about an inch long, shiny and black with bright white spots. Each adult has a pair of curved black and white antennae that are longer than their body. One obvious sign of the presence of this beetle is the large, round 3/8 to ½-inch holes the beetle chews to exit trees. These holes, which often ooze sap, are a clear sign of the Asian longhorned beetle and similar wood-boring pests. Piles of grass at the base of trees or in branch crotches indicate the presence of the Asian longhorned beetle or other wood pests.

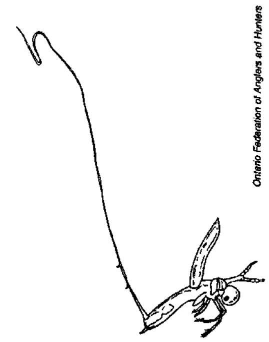
For more information on the Asian longhorned beetle, visit the APHIS web site at http://www.aphis.usda.gov, under hot issues, select "Asian longhorned beetle." This site offers information, contact numbers for each state, and facts on other foreign pests.

Fishhook Flea (*Cercopagis pengoi*)

Cercopagis pengoi, a member of the crustacean family, is one of the most recent invaders of the Great Lakes. This predatory cladoceran was first identified by Canadian scientists in Lake Ontario in early

August 1998. Its most probable route of Great Lakes introduction is believed to be through ballast water of oceanic vessels. *Cercopagis* is indigenous to the Caspian, Azov, and Aral seas and was reported to have invaded the Baltic Sea in 1992 (U.S. EPA Exotic Species Web Site 1999).

Cercopagis is similar to another crustacean invader of the Great Lakes, *Bythotrephes cederstroemi*. Both *Cercopagis* and *Bythotrephes* belong to the family *Cercopagididae*, and have long caudal processes with up to three pairs of barbs along the proximal end of the process. The tail comprises almost 80 percent of its body length. Both species occur in brackish and pure freshwater environments. In addition to sexual reproduction, *Cercopagidids* most commonly reproduce parthenogenically, which allows them to quickly establish new populations with a relatively small seed population. With use of a microscope, identifiable characteristics of *Cercopagis* are a unique loop at the end of its tail, as well as a pointed brood pouch which may contain eggs (U.S. EPA Exotic Species Web Site 1999).



Actual Size = 1 cm

An emerging problem that has been observed with the infestation of *Cercopagis* is the fouling of fishing lines for both the recreational and charter boat operations. The long, spiny tail of this crustacean can become entangled on fishing lines in clumps of hundreds of individuals. Anglers have resorted to cutting their lines, unable to reel them in (Ontario Federation of Anglers and Hunters Invading Species Homepage 1999).

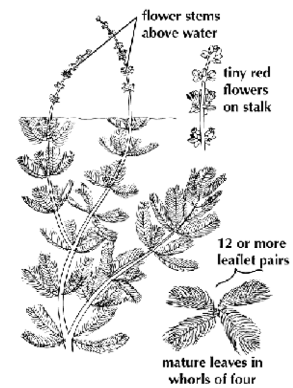
The U.S. EPA-Great Lakes National Program Office monitors biological and chemical data across all five Laurentian Great Lakes during two annual surveys, one in spring and one in summer. Currently, the zooplankton program takes vertical tows from depths of 20 and 100 meters, using 63 and 153 micron mesh nets, respectively. In 1998 the summer survey included a total of 72 sites, with eight sites sampled in Lake Ontario Aug. 5-7. *Cercopagis* was found in four of these eight sites, all occurring in the central basin. Lake Erie was sampled on this lake August 2-4, and no *Cercopagis* was found at any of the 20 sites sampled (U.S. EPA Exotic Species Web Site 1999).

It is believed that *Cercopagis* generally reside in the warmer, upper waters in the range of 20 meters. However, because of its large eye and brood sac, it is highly vulnerable to predation by larger planktivorous fishes. To avoid predation and possibly to follow migrating prey, *Cercopagis* does migrate below 20 meters during the day. In the early afternoon (site 49), high densities of *Cercopagis* were found below 20 meters. In contrast, all *Cercopagis* were above 20 meters at sunrise (site 55) (U.S. EPA Exotic Species Website 1999).

It is unknown at this point how long *Cercopagis* has inhabited the Great Lakes before first being reported and the extent of future impacts. Given the linkages between Lake Ontario and the other lakes, it is likely that this animal will spread throughout the lakes in time. Although it is too early to verify the effects that *Cercopagis* may have on the Great Lakes ecosystem, scientists are concerned that its high reproductive rates will generate high densities of this crustacean. This species can produce up to 13 offspring at one time, reproduce numerous times in one season, and produce “resting eggs” which can remain dormant over the winter. Potential ecological disruptions resulting from this new invader could include the decline of native zooplankton species as the number of *Cercopagis* increases As a consumer of zooplankton, *Cercopagis* could affect not only juvenile and small fish populations, but also larger fish that feed on the smaller fish. It also is conjectured that the long, spiny tail of *Cercopagis* will impede planktivores' consumption as is the case with the spiny water flea. More research is vital to determine the full impact of *Cercopagis* on the biodiversity and ecology of freshwater lakes and rivers (Ontario Federation of Anglers and Hunters Invading Species Homepage 1999).

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Eurasian watermilfoil is native to Europe, Asia and North Africa and thought to be the worst aquatic weed in the United States (Jacono 2000, University of Florida Center for Aquatic and Invasive Plants 2000). It was first identified in the U.S. in 1942 in a pond in Washington, D.C. (Jacono 2000), and is thought to have been intentionally introduced for use in aquariums (White pers. comm. 2000). It can now be found in all lower 48 states except southern Florida (Aquatic Plant Management Society).



Drawing courtesy of Center for Aquatic and Invasive Plants, University of Florida

Eurasian watermilfoil is a rooted, submersed, evergreen perennial (Aquatic Plant Management Society). It particularly likes nutrient rich areas and can grow to lengths of 6 to 9 feet in water anywhere from 1 to 15 feet in depth (University of Florida Center for Aquatic and Invasive Plants 2000, Aquatic Plant Management Society). Its stems branch out to produce many short, soft, feather-like leaves. Its flowers are reddish, very small and held above water on spikes many inches long. It occurs in lakes, ponds, shallow reservoirs, low flow areas of rivers and streams and can tolerate mild salinity and low water temperature (Jacono 2000, Aquatic Plant Management Society). The low water temperature provides Eurasian watermilfoil an advantage over native species in that it is able to begin its spring growth earlier. In Lake George, N.Y., for example studies have found that Eurasian watermilfoil has reduced native populations from 5.5 to 2.2 species per square meter just two years after its introduction. It also is quick to grow in areas of disturbance, particularly where there is nutrient loading, intense plant management and/or high motor boat use. In Put-In-Bay, Ohio, for example, water quality has been improving due to filtering of the water by zebra mussels, allowing natives to move back into the site. Eurasian watermilfoil has not been able to compete as well in this environment, and its population is declining, demonstrating the regulatory effect a healthier ecosystem can have on invasive species (Jacono 2000).

The thick vegetation of Eurasian watermilfoil also degrades water quality; restricts swimming, fishing and boating; and clogs water intakes. Decaying mats of vegetation also can foul local beaches and diminish aesthetic qualities (Jacono 2000). For wildlife, watermilfoil can deplete water oxygen levels and is a much less valuable food source for fish and waterfowl. Although it can provide cover for small fish, it is much too dense for any adult foraging that might have occurred with native plant species.

Eurasian watermilfoil reproduces through underground runners, called stolons, and through fragmentation, the method of most concern. A piece of the plant, one centimeter long, can multiply into 250 million new plants in one year, making it very easy to develop new colonies and very difficult to control (King County 1990). Boats chopping up individual plants are the main culprit of this type of spread.

In the Great Lakes states, watermilfoil is abundant. In Indiana, it is found in 175 lakes, at least 90 of which are in the St. Joseph drainage (Jacono 2000, White 2000). Illinois has actually found a decline in infested McCullom Lake due to the presence of the watermilfoil weevil, *Euhrychiopsis lecotei*. In Wisconsin, watermilfoil has been present since the 1960s and can now be found in 54 counties and 319 waterbody sites, more than any other state. In Michigan, it is found in many bays of Lake Michigan and northward through the lakes of the lower peninsula. In Minnesota, it arrived in 1987 and is now in 75 lakes and 4 streams, which stem out from the twin cities area. In efforts to deter its spread, the state of Minnesota has made it illegal to transport any aquatic vegetation (Jacono 2000).

Methods used to control watermilfoil are mechanical harvesting, hand harvesting, bottom screening, herbicides (Washington State Department of Ecology 1990) and biological control (University of Florida Center for Aquatic and Invasive Plants 2000). Mechanical harvesting is done with floating harvesters that dig weeds out by the roots. However, watermilfoil usually returns after two to three years due to fragments left by the process. Hand harvesting involves pulling weeds out by the root. This method can be effective but time consuming and requires gathering of all the pieces. Bottom screening involves laying a screen on the bottom of the lake, which acts to cut out light and space for the plants to grow (Washington State Department of Ecology 1990).

Euhrychiopsis lecontei, a native milfoil weevil, holds potential as a biological control agent for this invasive plant. Younger versions of the weevil feed on the tissue in the meristem and then on the stems. Adult weevils feed on both leaves and stems (University of Florida Center for Aquatic and Invasive Plants 2000). Native weevil populations have actually been found in many of the Great Lakes areas, including Minnesota, Wisconsin, Illinois and just recently in Indiana. However, their population levels are not dense enough to have an impact on the watermilfoil. This summer, a test of *Euhrychiopsis* as a feasible biocontrol agent will be run in three water bodies of Indiana. The tests are possible by a cooperative effort between Indiana's Lake and River Enhancement Fund through the Department of Natural Resources, Division of Soil Conservation, local lake associations, and the city of Bloomington Parks and Recreation Department. A contractor in Ohio, EnviroScience, Inc., will culture the weevils and stock the lakes. Progress of this biocontrol project will be monitored by staff at the University of Purdue (White 2000).

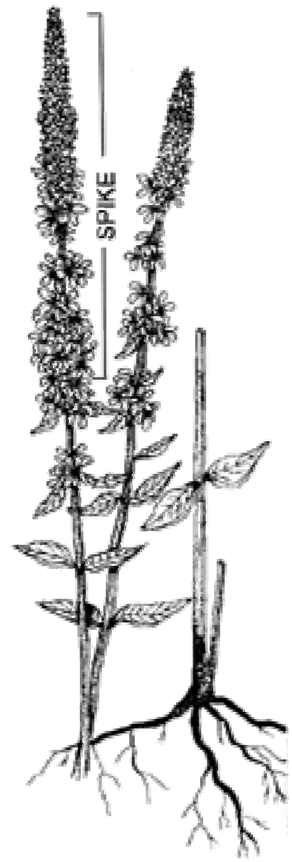
Prevention appears to be the most practical approach to managing Eurasian watermilfoil. In addition to managing for fragment dispersal, through boat inspections and restriction of aquatic vegetative trade, this nonindigenous plant has naturally shown difficulty in establishing where healthy populations of native plants are found. Protecting native plant populations and minimizing disturbance of natural habitats are both ways to impede watermilfoil infestations. As is the case with other nonindigenous species, watermilfoil is an aggressive colonizer and, given the opportunity, will quickly invade where space is available.

Purple loosestrife *(Lythrum salicaria)*

Purple loosestrife was first brought to North America from Europe in the early 1800s. Transmitted through the ballast water of European ships and directly by settlers for their flower gardens, purple loosestrife has now spread across much of the United States and Canada.

Purple loosestrife, although beautiful, has several devastating ecological effects. The plant thrives on moist soils, forming dense, nearly impenetrable stands that can rapidly degrade wetland areas. These stands are unsuitable as habitat for many wetland animals, including ducks, geese, muskrats, frogs and turtles. Because wetland areas are one of the most biologically diverse components of North America, threats to this vital habitat can ripple throughout the ecosystem, degrading areas where fish spawn and rice grows. A total of approximately 190,000 hectares of wetland, marshes, pastures and riparian meadows are affected by purple loosestrife in North America each year (Minnesota Sea Grant 1999).

These ecological disturbances have severe economic consequences. Due to the large area invaded by purple loosestrife and the habitat destruction it causes, millions of dollars are lost each year (Minnesota Sea Grant 1999). Moreover, as purple loosestrife continues to flourish, there is concern that it could spread further inland, encroaching on cropland and pasture land important to the economic health of the agriculture industry and farmers.



Drawing courtesy of Ontario Federation of Anglers and Hunters

Control options for purple loosestrife include digging and hand pulling, cutting, biological control and chemical control. The first two methods, digging and hand pulling and cutting, seek to destroy the plant at its area of invasion. These methods are time consuming and require broad public awareness to implement. Generating the necessary support can be a daunting task. Convincing the public that the purple loosestrife is a natural enemy is difficult given the plant's beautiful appearance. However, wildlife officials at all levels of the community (federal, state, university, environmental agencies, community organizations) have published flyers, created web pages and designed information for industry and the public to raise the profile of purple loosestrife. These efforts will make control more effective.

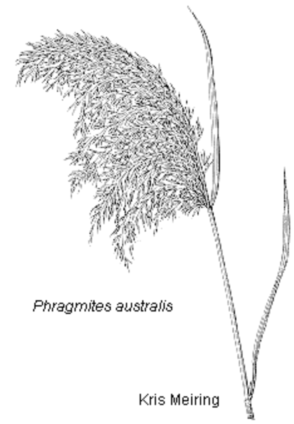
Chemical control can only be used in certain ecological areas. This is because attacking purple loosestrife with chemicals can have the unintended side effect of destroying other plants in the surrounding area. In the United States, the use of chemical controls for purple loosestrife near or in water has been approved; however, a permit is required.

Using these conventional methods to control purple loosestrife is difficult because of the reproductive capacity of the plant. Minnesota wildlife managers learned this lesson first hand when they tried conventional treatment methods. Managers found that while these methods killed individual plants, established stands allowed purple loosestrife to rapidly re-establish, producing nearly half a million seeds per square meter in wetland soil (Skinner 1998). In search for a more effective treatment, managers began to investigate biological control.

When a plant is replaced in a non-native environment, it usually leaves behind its natural predators. Biological control seeks to reintroduce a plant with it natural enemies, with the goal of reducing the number of invading plants. Biologists have tested several species of beetles, natural predators of purple loosestrife in Europe, to determine a control agent for use in the United States and Canada. In Minnesota, beetles were first released in 1992 with subsequent expansion in 1993, 1995 and 1997. The insects have established themselves at over 80 percent of the release sites (Minnesota Annual Report 1998). More research is being done to study the efficacy of this method of control, with the goal of 70 percent reduction purple loosestrife within 15-20 years. Thus far, results from Minnesota show that biological control agents require two years to kill purple loosestrife plants.

Common Reed *(Phragmites australis)*

Phragmites is thought to be one of the most widespread flowering plants in the world and can be found on every continent except for Antarctica. In North America there is evidence in the cores of 3000 year old peat from tidal marshes in Connecticut that *Phragmites* was here before Europeans arrived. There is also evidence of *Phragmites* in the remains of 600-900 A.D. year old objects found at an Anasazi archeological site in southwest Colorado. However, *Phragmites* spread began to be considered a problem in North America around the mid-1900s. It is thought at this time newly introduced Eurasian varieties were able to expand their ranges and that they may have produced an aggressive hybrid with the native species. It is also thought that the increase in human disturbance, specifically around salt water marshes, allowed an increase in this spread and even allowed native species to extend their ranges (Moore 1996). *Phragmites* is also perceived very differently in the east and west United States. In the west there is actually some concern about its decline in population and habitat, whereas in the northeast and east it is considered an aggressive invasive in natural wetland areas (Marks 1993).



Phragmites is a very large perennial grass; it can reach heights of up to 1-4 meters (Marks 1993). It also has grey-green leaves 2-3 centimeters wide, which wrap around the stem, and a brown tuft, at the top which remains through winter (Hindman). It can particularly be found in alkaline sites, brackish sites, acidic wetlands, flooded areas or water with a slow current, or where the underground water table is high and waters are stagnant. It is actually able to perform well in pristine areas, but is usually outcompeted by native species. *Phragmites* is also known to thrive in areas of disturbance and/or manipulation, such as railroad tracks, ditches or roadsides, especially where winter de-icing salt has accumulated. In these areas it has been found that *Phragmites* is also very quick to form the fence-like monotypic structure that it is its namesake, from the Greek word "phragma" meaning fence (Marks 1993).

The large mass of vegetation that can be formed by *Phragmites*, is developed through rhizomes. These rhizomes can reach up to 4 meters in length and form mats so dense in the soil that other species are prevented from establishing. The seeds that it does use for reproduction are dropped between November and January. *Phragmites* also offers little food or shelter to local wildlife, so at the same time it displaces native plant species, it also displaces local wildlife. This invasive plant can even attract new species, such as red-winged black birds, which enjoy perching on *Phragmites* stands (Marks 1993).

Control of *Phragmites* is done through cutting, burning, herbicide application, water level manipulation and biological controls. Cutting has been found to be effective if done at the right time, just before the end of July when most of the winter reserves would be removed with the top portion. A colony may be eradicated this way, but shoots must be taken so they do not resprout. Burning may be less effective because *Phragmites* tends to live on wet sites where roots are protected from damage. It also can be dangerous in that *Phragmites* may cause spot fires, sometimes as far as 100 feet away. When used together with another control such as an herbicide, cutting or water level manipulation, fire can be effective. After one of these methods is performed, fire can act to rid an area of the upper portion of the plant, allowing space for native species to migrate. In fall 1989, a freshwater area, spanning 20-30 acres was drained at Wertheim National Wildlife Refuge, N.Y. It was then burned the following winter and reflooded, effectively eliminating *Phragmites* from the treated area until 1992 (Marks 1993).

Herbicides such as Rodeo TM (a glyphosate product) can be useful if done after the tasseling stage in the fall and sprayed onto the foliage of the plant. Delmarva Power in Maryland sprayed a large area intensively the first year, with backpacks and helicopters, then spot sprayed the following year yielding 90 percent to 95 percent elimination (Marks 1993).

Water manipulation also has been shown to decrease the presence of *Phragmites*. In Fairfield, Conn. a self-regulating tide gate was installed in a diked marsh, which allowed water level fluctuation and saltwater to increase. This management approach resulted in a 1-3 foot height reduction, and a density decline from 11.3 plants/square meter to 3.3 plants/square meter occurred with local *Phragmites* after only one year. It has since continued to decline. Restoration of natural water flows including water level manipulation and increases in salinity, can be helpful controls to *Phragmites* populations (Marks 1993). Cornell University also is looking into a variety of biological controls, many that may already be native to the United States (Kearns 2000). Although none are known at this point, studies conducted in Europe have shown that gall-forming and stem-boring insects may reduce growth (Marks 1993).

The state of New York controls *Phragmites* through cutting and visual assessments (Department of Environmental Conservation), cutting and herbicide (National Audubon Society), and water level manipulation and burning with visual assessments (Wertheim National Wildlife Refuge). In Pennsylvania at the Tinicum National Environmental Education Center they perform chemical application with restoration and seeding. In Ohio, Arcola Creek Wetland and Morgan Marsh control *Phragmites* by cutting before the end of July and using aerial photographs to determine its spread (Marks 1993).

Garlic Mustard ***(Alliara petiolata)***

Garlic mustard is a species native to Europe and Asia (Save the Dunes Council, Inc. 2000). It is thought to have been brought to North America by European settlers for use in cooking, to increase vitamin A and C content and add garlic flavoring, and in medicine for the treatment of gangrene and ulcers. More recently it has been used in natural areas to prevent erosion. It was first identified in the United States in 1868 on Long Island, N.Y. and by 1990 it had spread to a total of 29 states. Although the main mode of spread is unclear, it is thought that the trampling of the soil by white-tailed deer exposed the seeds, prompting them to germinate (Cornell University 2000).

Garlic mustard itself is a biennial herb which acts to aggressively displace native grasses, herbs and tree seedlings (Cornell University 2000). It is common in woodland areas and can be found in rich, moist, upland forests and wooded stream banks. It is also shade tolerant and will readily invade disturbed sites such as roadsides, trail edges or sites of construction (Virginia Native Plant Society 2000). The plant itself can grow to between 5 and 46 inches, forming a rosette of kidney-shaped leaves the first year, remaining green throughout the winter, and the second year producing white flowers which act to disperse seeds then die (Cornell University 2000). The seeds can then germinate that same year if conditions are right or wait until the following spring (Mortell 2000).

Garlic mustard has a great ability to reproduce at high rates (Save the Dunes, Inc. 2000) with each plant producing as many as 168-868 seeds per plant (Cornell University 2000). As many as 20,000 seeds per square meter have been found, with this number decreasing to about 50 percent by the end of May (Cornell University 2000). Once the seeds are sown they are quick to grow, forming a blanket of rosette leaves over the forest floor and crowding out native vegetation whose growth period typically lags behind that of garlic

Drawing courtesy of Virginia Department of Conservation and Recreation mustard. Like other invasive species, garlic mustard also has very few predators in North America, giving it another advantage over native species (Save the Dunes Council, Inc. 2000). This displacement of native species leads to a decline in total biodiversity, eliminating certain plant species and thus displacing the insects and animals that may rely on them for food and shelter.

The control of garlic mustard depends on the severity of the infestation. For light infestations, hand pulling or stem cutting can be effective, with the optimal time for control being at emergence between early to mid-April (Save the Dunes Council, Inc. 2000). For more severe cases, herbicides (Virginia Native Plant Society 2000) or prescribed fires can be useful (Cornell University 2000). Since garlic mustard overwinters in a green form, the non-selective biodegradable herbicide Glyphosate can be used. Applied in the late fall after other species have lost their green appearance, this herbicide should prove effective. Most likely, herbicide application would have to be reapplied over two to three years for adequate management (Virginia Native Plant Society 2000). Prescribed fires also can be effective over repeated spring burns just prior to the growth of most native plants (Cornell University 2000). Despite these efforts, prevention, as with other invasive species, appears to be the key. Garlic mustard has difficulty establishing in sites where healthy native populations can be found. Therefore, the management of natives and the avoidance of disturbance will significantly increase the ability of an ecosystem to fend off infestations, thereby saving thousands of dollars in management costs.

Common Buckthorn (*Rhamnus cathartica*)

Common buckthorn is native to Eurasia and North Africa and was introduced into northeastern North America sometime around the late 1800s. In Canada it was first identified in the late 1890s and can now be found from Nova Scotia to Alberta. In the United States it is more widely spread throughout the northeast and into Michigan, Illinois, Indiana, Ohio, Wisconsin, Minnesota and the east half of the Dakotas. Because it has few predators and a hardy nature, it was originally brought over as an ornamental shrub to be used as hedges and windbreaks in farmland areas (Haber 1997). Its spread has since become a problem because of its ability to tolerate a wide range of moisture and light levels and its significant seed production, with each seed having a high rate of viability and germination (Environment Canada 1999).


Drawing courtesy of Environment Canada

Buckthorn is a small tree or shrub reaching heights of up to 25 feet and 10 inches in diameter (Minnesota DNR 2000). Its bark is dark gray or brown, is roughly textured and has spines protruding from the end of its branchlets (Haber 1997). The leaves are wide and elliptical, being lighter green underneath and remaining green into the fall (Minnesota DNR 2000). Buckthorn also has small green flowers and small black fruits that contain three to four seeds and poisonous substances called rhamnin and rhamnetin. These substances can cause diarrhea and vomiting in humans but only create a laxative effect in birds, which are the main consumers of the fruit (Haber 1997).

Buckthorn is found in moist to dry upland sites, including woodlands, savannas, upland and floodplain forests, edges of woodlands, fencerows, prairies, open fields and riparian oak forests. It appears to grow best in moist soils (Haber 1997, Environment Canada 1999). Because birds are the main method of dispersal, most plants tend to be found in areas where birds have places to perch, such as woodlands. In a study conducted by New York it was found that although open field seeds and seedlings tend to do better, the ability for birds to reach these sites limited its colonization. However, in wooded areas rodents were found to eat more of the seeds, also decreasing colonization but to a lesser extent (Haber 1997).

Buckthorn is an aggressive invader. Its growth that is seasonally earlier, rapid and irregular allows it to shade out and thus eliminate most native species in an area. It is also thought that buckthorn may be allelopathic, releasing a substance into the soil which acts to inhibit the growth of surrounding vegetation. In addition, as an economic concern, buckthorn acts as an alternate host to the oat rust fungus, a particular problem for farmers who have planted buckthorn as a windbreak (Environment Canada 1999).

Control for buckthorn is mainly prescribed fire, stem girdling or cutting and herbicide application (Environment Canada 1999). Trial fires have shown that fire must be performed for five to six years before proving effective (Haber 1997). It is also possible that roots may not be killed in these fires if the buckthorn is found on a moist site. Fire also may not be the most appropriate method of control given environmental conditions and local species concerns (Environment Canada 1999).

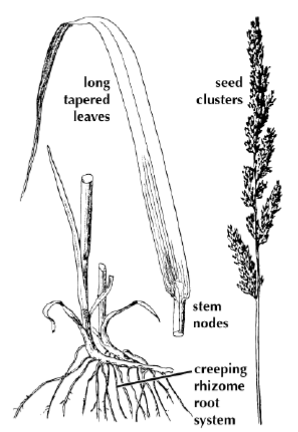
Stem cutting and girdling followed by herbicide application is another alternative. Late fall application appears to be the most practical, since most herbicides are designed to work on green shrubs and the leaves of the buckthorn remain green much longer into the fall than native species. Herbicides such as Trimec, Garlon 3A and Round-up applied immediately after stem cutting can be effective. One important aspect to note is that with the displacement of native species, buckthorn may be acting as the only local nesting site for birds. For this reason, it may be desirable to control the species at a more gradual rate. One solution is to take advantage of buckthorn functioning as a dioecious species with male and female shrubs. Eliminating the female shrubs would prevent the seed bank from increasing but still allow enough male shrubs left for nesting. Biological control research has also been done in Canada and Europe where they have studied plant pathogenic viruses and identified the cucumber mosaic cucumovirus as a potential control (Haber 1997).

In the United States the Minnesota Interagency Exotic Species Task Force ranked the infestation of common buckthorn as severe and have been developing seasonal controls. From late March to early May they have been using prescribed burns. They have found that despite the vulnerability of seedlings to fire, they usually grow in areas without much litter making it difficult to establish an effective fire. However, cuttings done in the following fall and left on the floor can help to provide fuel for the spring burns. In May to October herbicide application is performed with appropriately diluted Garlon 3A applied directly to the stumps. From mid-August to October a cut is done followed by an herbicide application. During winter, appropriately diluted Garlon 4 with an oil, such as Penevator, and a dye has been found to be effective (Minnesota DNR 2000).

Reed Canary Grass *(Phalaris arundinacea)*

Reed canary grass can be found throughout the world except for Antarctica and Greenland (Hutchinson 1990). Although the variety native to North America is not considered a threat to local Great Lakes ecosystems, the introduced Eurasian variety poses risks to native species.

Initially Reed canary grass was found to be useful for livestock foraging, silage and hay in Europe (King County 2000). About 150 years ago this variety was brought to the United States for that same purpose (Harlow). The species was also found to be useful as a water filter for pollution and was



Drawing courtesy of King County Water and Land Resources Division, Washington promoted as a "marsh hay" in many wetland areas (King County 2000, Upper Midwest Environmental Sciences Center 2000). The thought of these benefits facilitated the spread of these varieties throughout the United States and Canada. Now it has become virtually impossible to tell one variety from the other. Many also believe that aggressive hybrids have developed. This makes it incredibly difficult to develop an accurate map of the invasive species and adequately implement measures to protect the native variety (Environment Canada 2000).

The European variety and possible hybrids of reed canary grass have since come to be significant threats to the health of wetland areas. They have been described as aggressive, competitive, persistent, hardy and rapidly growing, replacing natives after only a few years (Hutchinson 1990, King County 2000). It also has been noted, especially in Minnesota and Wisconsin, to quickly form monocultures. The rapid growth of reed canary grass allows it to completely shade out native species. The longer the stand remains monotypic, the more likely the seed bank will be depleted of any viable native species (Environment Canada 1999).

The plant itself is a perennial grass growing as high as 2 meters. Its leaves are long (3 ½ to10 inches), thin and flat with a rough texture on both sides (Hutchinson 1990). It can reproduce both by seed and vegetatively by rhizomes. These rhizomes are the most problematic and can spread at an incredibly high rate, forcing out other grasses and plants, creating monotypic stands, and subsequently decreasing overall biodiversity.

The grass can be found in moist areas including wetlands, marshes, wet prairies, wet meadows, fens, lake shores and any other poorly drained areas. It can tolerate flooding and grow in wet or dry areas but does best in fertile, moist to wet soils. Like many other invasive species it is also quick to colonize areas of disturbance (Hutchinson 1990, Upper Midwest Environmental Sciences Center 2000).

Control options for reed canary grass consists of hand pulling, prescribed fire, herbicides or mowing. Hand pulling done two to three times a year for five years can also be very effective, but is only practical in small areas (Environment Canada 1999). Fire performed yearly in the early spring can be effective on larger sites; however, control is not evident for five to six years (Hutchinson 1990). Fire will most often be effective when the stand has not been a longstanding monoculture and the native seeds have not been depleted. Herbicides such as Rodeo and Amitrol applied in early spring, before other species have begun their green growth, can work well, as can Dalapon, a monocot and grass herbicide (Hutchinson 1990). The most effective method of control, however, appears to be the use of shade. Reed canary grass is shade intolerant and planting favorable tree species around the grass can provide enough shade to adequately hinder growth of the species. Other species such as sedges, rushes, willow, choke cherry and/or red osier dogwood can then be planted in place of the grass (King County 2000). Despite these controls, however, the spread of reed canary grass is so wide that it will most likely always have some presence in our wetland areas (Kearns 2000).

A few important aspects to note are that currently no controls for the grass exist in Canada, which may make control efforts near the border difficult (Environment Canada 1999). Also, due to the difficulty in distinguishing between the native species, hybrids and the Eurasian variety, it will be difficult to protect the native variety during management.

Hydrilla (*Hydrilla verticillata*)

Although hydrilla is not considered to be a problem in the Great Lakes region it has become a significant problem in almost all other areas of the United States, and there is much concern that it will eventually make its way into the Great Lake system.

It can be found in Asia, Africa and Australia and was introduced into the United States in Florida during the 1950s as a plant used in aquariums (Stein and Flack 1996). Because of hydrilla's ability to tolerate many different environmental conditions, once released it was easily able to spread through natural waterways. It has now been noted as far west as California and Washington and east into Connecticut, Delaware, Maryland, North and South Carolina, and Virginia (McFarland, Poovey and Madsen 1998).

Hydrilla can be found in environments ranging from still to flowing water, low to high nutrient levels, pH's between 5 and 9, brackish water, and temperatures ranging from 12˚ Celsius to 28˚ Celsius (with 28˚Celsius being its optimal) (McFarland, Poovey and Madsen 1998). Areas of agricultural and urban runoff have been found to promote the spread of this species (Stein and Flack 1996).

Hydrilla also has a unique ability to photosynthesize under low light levels, giving it the advantage of inhabiting deeper, darker waters where most other plants cannot grow (Jacono 2000). It can then migrate upward toward shallower waters, forming thick mats of vegetation on the water surface, where 70 percent of its biomass is found (Stein and Flack 1996). These thick mats, which can be thick enough for ducks to walk on, are rooted into the ground. In addition to making swimming, boating and fishing virtually impossible these mats also shade out most native vegetation. At a growth rate of up to an one inch a day, hydrilla also can be very effective at blocking pipelines for irrigation and power generation (University of Florida Center for Aquatic and Invasive Plants 2000).

Drawing courtesy of the Center for Aquatic and Invasive Plants, University of Florida

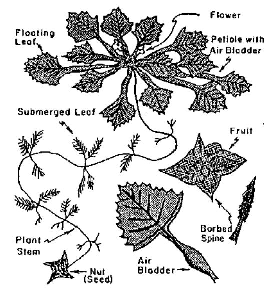
Like Eurasian watermilfoil, its main method of dispersal is fragmentation (although it can reproduce by vegetative buds, subterranean tubers and seeds, these are not thought to be significant methods of new colonization) (McFarland, Poovey and Madsen 1998). Pieces of the plant can easily get caught up in boats and transported to other areas or dropped in the same lake, increasing its current population. Pieces of the plant also can be accidentally transported on other aquatic vegetation or through the aquarium trade in which it is still sold (Jacono 2000, Kearns 2000). Again, like Eurasian watermilfoil, just one small fragment of hydrilla can cause a significant amount of damage. One piece can create a large mass in only a couple weeks, and a few acres can explode into thousands of acres in only a couple years (Stein and Flack 1996).

This rapid growth and density of vegetative cover can alter both the physical and chemical characteristics of a waterbody. Hydrilla has been linked to lower oxygen levels, fish kills and a decrease in the weight of sport fish when occupying the majority of the water column. The loss of open space and the natural vegetation gradient also acts to decrease available forage for fish and open water feeding opportunities for birds, displacing them to other areas and thereby impacting the ecosystem's overall biodiversity (Jacono 2000).

Control of hydrilla appears virtually impossible in areas of infestation, so prevention of its introduction and spread are critical. Mechanical and herbicide application have been found to be somewhat effective but with its fast growth and ability to spread by fragmentation, it is difficult to eliminate from any waterway. In Florida where half of the state's waterways are infested, there are now yearly inspections of the state's lakes (Stein and Flack 1996), an approach that should be considered in the Great Lakes region. Although it is thought that the cooler temperatures of the north may play a role in impeding its growth and spread, many who study the species believe that it will eventually enter the Great Lakes ecosystem (McFarland, Poovey and Madsen 1998).

Water Chestnut *(Trapa natans)*

Like hydrilla, water chestnut has not yet entered the Great Lakes ecosystem. It has, however, become a significant problem in the northeast United States and there are projections that it is only a matter of time until water chestnut establishes itself in the Great Lakes.



Water chestnut
(Trapa natans L.)

Drawing courtesy of Vermont Department of Environmental Conservation and Water Quality Division

Water chestnut is native to Eurasia and has invaded paleotropical areas and warm temperate zones, found in Australia and northeast North America. Because the fruits are used for food and medicine and have noted "magical" properties, the species was distributed in Europe, Asia and eventually, through settlement, found its way to the United States. It was first recorded in the United States in 1874 as being cultivated by Harvard botanist Asa Gray in Cambridge, Mass. A few years later, in 1879, it was found in the nearby Charles River and by the 1940s had become well-established in the northeast part of the country (Haber 1999; McFarland, Poovey and Madsen 1998). Since that time it has infested the Hudson and Potomac rivers, Lake Champlain and the Connecticut River Valley and can be found in the states of Maryland, Massachusetts, New York, Pennsylvania and Vermont. It also was reported recently (1998) for the first time in southwest Québec on a tributary of the Richelieu River, which extends from Lake Champlain. Water chestnut is now listed under federal regulations, which prohibit interstate sale and transport of the species. It also is considered a noxious weed in Arizona; is illegal to possess, import or distribute in South Carolina; and is illegal to possess in Florida (Haber 1999).

The plant itself is a floating annual aquatic requiring a soft substrate for anchoring since it has no primary root. A cord-like stem extends upward ending in a rosette of leaves floating on the water's surface. These rosettes can be up to three layers thick, and up to 50 rosettes of leaves can be found per square meter (McFarland, Poovey and Madsen 1998). This vegetation can also act to shade out native species and make swimming, boating and fishing very difficult. The plant does not provide good forage for wildlife, and its decomposition and detritus in the fall are thought to result in lower oxygen levels, which can negatively impact local aquatic life (Haber 1999).

One concern held by many recreational water users is water chestnut's thickly spined fruit. As an annual, the plant is produced entirely by seeds. These seeds over-winter from the previous season and germinate in early May. Leaves then form by June and flowers appear July through September. After insect pollination, the flower droops down into the water and the thickly spined fruit develops, anchoring the plant to the area (McFarland, Poovey and Madsen 1998). The spined fruit can be dangerous for swimmers or other recreational water users, causing cuts or puncture wounds.

Rapid rate of production is also a serious concern. In early May each seed is capable of producing 10 to 15 rosettes and each rosette is capable of producing 20 seeds. Meaning that one seed could produce up to 15 rosettes, which could produce up to 300 seeds, leading potentially to 4500 new rosettes the following spring only the second year after initial seed germination, an increase of 675 percent. Water chestnut also has been found to increase its productivity in response to low population densities through allocating more resources to reproduction (Haber 1999).

The primary approach to controlling water chestnut has been through mechanical harvesting, which is most effective in small areas. In large areas, however, mechanical harvesting does not eradicate all plants unless done repeatedly over a number of years. Management through biological control has been researched. A study conducted in 1992 and 1993 in China, Japan, South Korea and the Russian Far East found no effective predators. The same results applied in a 1995 study conducted by countries in central Europe. The possibility of biological control may be found in warmer climates of India, which would prove useful if water chestnut begins to spread southward from its current northeastern range (Haber 1999). In the Great Lakes region, it appears that prevention is the only feasible approach to the management of water chestnut. Due to the difficulty in controlling this nonindigenous species, it is critical to find ways to ensure that it does not get into the system. In cases where water chestnut does invade, immediate detection will be needed to implement control measures.

Conclusion: Future Directions on Great Lakes Nonindigenous Invasive Species Programs

The recommendations and findings that emerged from work on this briefing paper and the associated workshop on Great Lakes nonindigenous invasive species (sponsored by U.S. EPA-GLNPO in Chicago, Oct. 20-21, 1999) revolved around the following themes:

- prevention of introduction and dispersal
- control of established populations
- detection and monitoring
- education/outreach
- multilevel management coordination

This guidance is presented to the U.S. EPA, symposium attendees and other interested parties for consideration in the development of future NIS prevention and control programs. Although the discussion that follows reflects the general consensus of project participants, it should be noted that no effort was made to prioritize individual points.

Prevention of Introduction and Dispersal

The prevention of new introductions of nonindigenous invasive species is widely accepted as the most effective way to manage NIS problems and is considered the first line of defense against invasions.

- To more effectively predict and prevent future NIS invasions, a paradigm shift is needed towards a more proactive approach to NIS research and management efforts.
- The federal government needs to take a leadership role in the area of NIS prevention.
- Ballast water transport, identified as a leading source of ANS introductions in the Great Lakes basin, will require enhanced management in terms of policy development and application of treatment technology.
    - Further investigation of use of the Clean Water Act through the application of National Pollutant Discharge Elimination System permits and standards is recommended as a potential approach to mitigate ANS introductions through ballast water discharges.
    - Assessment of the feasibility of various treatment technologies for ballast water is needed, including shoreside facilities, chemical and heat treatment, and filtration, among others. As part of this assessment, options to handle vessels reporting no ballast on board (NOBOB) need to be investigated.
- Although ballast management is the vector that has drawn the most attention in terms of prevention efforts, it is recommended that managers also consider other high risk pathways of introduction, particularly involving terrestrial species. An example of a significant vector introducing terrestrial species is the horticultural business.
- Monitoring is identified as a prevention tool for species identified as potential invaders. (It was noted, however, that the approach targeting potential invaders has not yet been tested for its efficacy, with concern that this approach to monitoring does not take into account all of the unknown risks.)

Control of Established Populations

Although control of established NIS population tends to be the focal point of management efforts, this reactive approach to management is not preferred since very few NIS infestations have been successfully limited or eradicated. Control options have become increasingly controversial with greater scrutiny of the efficacy and potential environmental impacts of existing control programs.

- To most effectively make use of limited resources, it is important to prioritize through the application of criteria in regard to the species for which NIS control measures should be applied. As part of this process, it is recommended that the cumulative effects of species are taken into account. For example, an individual species may not appear to pose a threat, but on a cumulative basis, this species may cause significant problems in co-existence with other species.
- As part of the process of determining NIS control plans, all potential control measures should be considered including, physical, chemical and biological, among others.
- As part of NIS control efforts, there is a particular need for public education on the benefits and risks of using various control options, such as chemical, physical, biological and integrated pest management. Consideration also should given to the risks that emerge when control measures are not implemented. A balanced, accurate presentation of this information is critical in assisting decisionmakers, as well as public and private stakeholders, in making sound choices for appropriate control programs.
- Potential environmental impacts should be an important consideration in the evaluation of NIS control options.
- The level of habitat and resource quality should serve as criteria in the process of prioritizing where control efforts should be focused. For instance, pristine areas may be considered to hold zero tolerance for nonindigenous species, whereas in areas where some ecological degradation has occurred, there may be some tolerance of species.

Detection and Monitoring

Although detection and monitoring of nonindigenous invasive species should be considered the foundation of prevention and control efforts, this aspect of NIS programming does not hold a high profile in research and management paradigms for either terrestrial and aquatic nonindigenous species. There is a strong need for programmatic development in the area of detection and monitoring to facilitate quick response in the implementation of eradication/control measures. As part of detection and monitoring efforts, there is a need for visual assessments of NIS invasions and their progression to support scientific research and public and policy decisionmaking.

- Compile baseline data on distribution, ecology and relative threats regarding nonindigenous invasive species in region. Detection and monitoring methods and data formats should be standardized as much as possible to facilitate useful information sharing.
- Based on a database that is continually updated, develop regional watershed lists on nonindigenous invasive species.
- Provide incentives for taxonomic experts to detect, report or evaluate nonindigenous invasive species.
- Decrease the time between detection and reporting for effective NIS management (e.g., control/eradication).
- Utilize volunteers to implement program activities.
- Integrate detection as part of research to serve as a basis for action.

- Predict future invaders to facilitate early NIS detection and prompt action for eradication/control.
- Develop regulatory support to facilitate action during the window of opportunity after detection while eradication is still possible.
- Establish an emergency funding source for eradication of new nonindigenous invasive species.
- In the development of detection and monitoring programs for invasive species, partnerships need to be formed to examine as many biological components as possible, since the overall impact to the ecosystem is unknown.

Education/Outreach

An informed and educated public, that includes all stakeholders, is widely recognized as the cornerstone of an effective NIS prevention and control program. To achieve this end, it is essential that information and education (I/E) efforts convey accurate facts that are appropriately targeted and offer a consistent message on a multijurisdictional level.

- The Great Lakes Panel's *Information/Education Strategy for Aquatic Nuisance Prevention and Control* is a recommended model for use by appropriate entities to address NIS problems through consideration, among others, of the following objectives:
    - Identify vectors of NIS introduction and dispersal, and encourage target groups to comply with identified practices to minimize further problems and to implement appropriate solutions.
    - Provide regional coordination of the development and dissemination of information on NIS issues in efforts to disseminate consistent, non-conflicting information regarding prevention and control initiatives.
    - Engage the active involvement of Great Lakes regional policymakers and aquatic user groups in the promotion of NIS prevention and control programs.
    - Facilitate adequate funding to implement feasible solutions to NIS problems.
    - An ecosystem approach should provide the foundation for I/E programs with the purpose of raising awareness on NIS issues and generating support for action on NIS prevention and control.
    - The NIS issue should be presented with consideration for both the aquatic and terrestrial components to promote a balanced understanding among stakeholders and to facilitate effective management on NIS prevention and control.
    - To get the NIS issue on the agenda of political decisionmakers, high-profile aspects of the problem, such as human health risks and biodiversity threats, should be effectively communicated through educational channels.
    - To generate broad-based support for the NIS issue, it is recommended that both ecological and economic impacts resulting from NIS invasions are documented and presented. Economic impacts should be assessed in terms of the costs resulting from not taking action and potential benefits from taking preventative action.

Coordination of Multijurisdictional Efforts

The prevention and control of nonindigenous invasive species have global implications that require policies and programs at multijurisdictional levels of government. Coordination between existing federal, regional and state/provincial programs will be critical in effectively addressing problems caused by the introduction and spread of nonindigenous species.

- Regional, federal, state/provincial and local agencies need to work together early in the budgetary planning stages for NIS programs. Related appropriations requests should be presented to Congress under one umbrella, when appropriate, representing needs on a regional basis.
- Staffing for NIS programming should be coordinated at the federal, regional, state/provincial and local levels.
- In terms of management regarding NIS prevention and control, there is a need for reliable communication among all levels of government
- Partnerships need to be formed around the world to design detection and monitoring programs in efforts to prevent future invasions.
- Internet technology should be employed to facilitate efficient coordination among cooperating agencies and individuals.
- Infrastructure responsible for NIS management (e.g., invasive species councils operating on both the state/provincial and federal level) should be organized to address both aquatic and terrestrial aspects of the problem.
- To facilitate NIS program implementation, funding needs to be coordinated on a multijurisdictional level to achieve the following: permanent staffing, training sessions, enforcement of regulations, monitoring projects, grants that support control efforts and related research, educational material, conferences, support for state/regional invasive species councils, a rapid response network, and a GIS-based database.

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APPENDIX A

Documented Introductions of Non-indigenous Aquatic Flora and Fauna into the Laurentian Great Lakes Basin: 1800s to 1993

Mills, E.L., J.H. Leach, J.T. Carlton, C.L. Secor. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. J. Great Lakes Res. 19(1)

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TABLE 1. Location abbreviations of exotic species in the Great Lakes.

Location	*Code*
Lake Ontario	O
Lake Erie	E
Lake St. Clair	StC
Lake Huron	H
Lake Michigan	M
Lake Superior	S
tributaries	T

TABLE 2. Codes for transport mechanisms of exotic species entering the Great Lakes.

Mechanism	Code
Release (Deliberate)	R(D)
Release (Unintentional)	R(U)
Release (Aquarium)	R(AQ)
Release (Cultivation)	R(C)
Release (Fish)	R(F)
Release (Accidental)	R(A)
Shipping activities	s
Ships (Ballast Water)	S(BW)
Ships (Solid Ballast)	S(SB)
Ships (Fouling)	S(F)
canals	c
Railroads and Highways	RH

TABLE 3. Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic fauna of the Great Lakes. For location and introduction mechanism codes see Tables 1 and 2.

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Fish						
Petromyzontidae	*Petromyzon marinus*	sea lamprey	Atlantic	1830s	Lake Ontario	C, S(F)
Clupeidae	*Alosa pseudoharengus*	alewife	Atlantic	1873	Lake Ontario	C, R(F)
Cyprinidae	*Carassius auratus*	goldfish	Asia	<1878	widespread	R(D), R(AQ) R(F), R(A)
	Cyprinus carpio	common carp	Asia	1879	widespread	R(D)
	Notropis *buchanani*	ghost shiner	Mississippi	1979	Thames River (StC)	R(F)
	Phenacobius mirabilis	suckermouth minnow	Mississippi	1950	Ohio(E)	C, R(F)
	Scardinius erythrophthalmus	rudd	Eurasia	1989	Lake Ontario	R(F)
Cobitidae	*Misgurnus anguillicaudatus*	oriental weatherfish	Asia	1939	Shiawassee River (H)	R(A)
Ictaluridae	*Noturus insignis*	margined madtom	Atlantic	1928	Oswego River (0)	C, R(F)
Osmeridae	*Osmerus mordax*	rainbow smelt	Atlantic	1912	Crystal Lake (M)	R(D)
Salmonidae	*Oncorhynchus gorbuscha*	pink salmon	Pacific	1956	Current River (S)	R(A)
	Oncorhynchus kisutch	coho salmon	Pacific	1933	Lake Erie	R(D)
	Oncorhynchus nerka	kokanee	Pacific	1950	Lake Ontario (T)	R(D)
	Oncorhynchus tshawytscha	chinook salmon	Pacific	1873	All Lakes but S	R(D)
	Oncorhynchus mykiss	rainbow trout	Pacific	1876	Lake Huron (T)	R(D)
	Salmo trutta	brown trout	Eurasia	1883	Lakes Ontario (T)	R(A)
					and Michigan (T)	R(D)
Poeciliidise	*Gambusia affinis*	western mosquitofish	Mississippi	1923	Cook Co., Illinois	R(D)
Gasterosteidae	*Apeltes quadracus*	fourspine sticklebacks	Atlantic	1986	Thunder Bay (S)	S(BW)
Percichthyidae	*Morone americana*	white perch	Atlantic	1950	Cross Lake (O)	C
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	Atlantic	1971	Jamesville Res. (O)	R(AQ), R(F)
	Lepomis humilis	orangespotted sunfish	Mississippi	1929	Lake St. Mary's (E)	C
	Lepomis microlophus	redear sunfish	Southern U.S.	1928	Inland Indiana (M)	R(D)
Percidae	*Gymnocephalus cernuus*	ruffe	Eurasia	1986	St. Louis River (S)	S(BW)
Gobiidae	*Neogobius melanostomus*	round goby	Eurasia	1990	St. Clair River (SW)	S(BW)
	Proterorhinus marmoratus	tubenose goby	Eurasia	1990	St. Clair River (StC)	S(BW)
Molluska						
Valvatidae	*Valvata piscinalis*	European valve snail	Eurasia	1897	Lake Ontario	S(SB)
Viviparidae	*Ciparsgopaludina chinensis malleata*	Oriental mystery snail	Asia	1931	Niagara River	R(AQ)
	Cipangopaludina japonica		Asia	1940s	Lake Erie	R(D)
	Viviparus georgianus	' banded mystery snail	Mississippi	<1906	Lake Michigan (T)	R(AQ)

Continued

TABLE 3. Continued

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Bithyniidae	*Bithynia tentaculata*	faucet snail	Eurasia	1871	Lake Michigan	S(SB), R(D)
Hydrobiidae	*Gillia altilis*	snail	Atlantic	1918	Oneida Lake (O)	C
Pleuroceridae	*Elimia virginica*	snail	Atlantic	1860	Erie Canal	C
Lymnaeidae	*Radix auricularia*	European ear snail	Eurasia	1901	Chicago (M)	R(AQ), R(A)
Sphaeridae	*Sphaerium corneum*	European fingernail clam	Eurasia	1952	Rice Lake (H/O)	Unknown
	Pisidium amnicum	greater European pea clam	Eurasia	1897	Genesee (O)	S(SB)
Corbiculidae	*Corbicula fluminea*	Asiatic clam	Asia	1980	Lake Erie	R(A), R(AQ), R(F)
Dreissenidae	*Dreissena polymorpha*	zebra mussel	Eurasia	1988	Lake St. Clair	S(BW)
	Dreissena sp.	zebra mussel	Eurasia	1991	Lake Ontario	S(BW)
Unionidae	*Lasmigona subviridis*	mussel	Atlantic	<1959	Erie Canal	C
Crustaceans						
Cladocera	*Bythotrephes cederstroemi*	spiny water flea	Eurasia	1984	Lake Huron	S(BW)
	Eubosmina coregoni	water flea	Eurasia	1966	Lake Michigan	S(BW)
Copepoda	*Eurytemora affinis*	calanoid copepod	widespread	1958	Lake Ontario	S(BW)
	Skistodiaptomus pallidus	calanoid copepod	Mississippi	1967	Lake Ontario	R(A), R(F)
	Argulus japonicus	parasitic copepod	Asia	<1988	Lake Michigan	R(F), R(AQ)
Amphipoda	*Gammarus fasciatus*	gammarid amphipod	Atlantic	<1940	Unknown	S(BW), S(SB)
Oligochaetes						
Naididae	*Ripistes parasita*	oligochaete	Eurasia	1980	North Channel (H)	S(BW)
Tubificidae	*Branchiura sowerbyi*	oligochaete	Asia	1951	Kalamazoo River (M)	R(A)
	Phallodrilus aquaedulcis	oligochaete	Eurasia	1983	Niagara River	S(BW)
Other Invertebrates						
Platyhelminthes	*Dugesia polychroa*	flatworm	Eurasia	1968	Lake Ontario	S(BW)
Hydrozoa	*Cordylophora caspia*	hydroid	Unknown	1956	Lake Erie	R(A)
	Craspedacusta sowerbyi	freshwater jellyfish	Asia	1933	Lake Erie (T)	R(A)
Insects	*Acentropus niveus*	aquatic moth	Eurasia	1950	Lake Ontario, Erie	R(A)
	Tanysphyrus lemnae	aquatic weevil	Eurasia	<1943	Unknown	Unknown
Disease pathogens						
Bacteria	*Aeromonas salmonicida*	furunculosis	Unknown	<1902	Unknown	R(F)
Protozoa	*Glugea hertwigi*	microsporidian parasite	Eurasia	1960	Lake Erie	R(F)
	Myxobolus cerebralis	salmonid whirling disease	Unknown	1968	Ohio (E)	R(F)

TABLE 4. Origin, date and location of first sighting, and entry mechanism(s) for non-indigenous aquatic plants and algae of the Great Lakes. For location and introduction mechanism codes see Tables 1 and 2.

Tax on	Species	Common Name	Origin	Date	Location	Mechanism
Algae						
Chlorophyceae	*Enteromorpha intestinalis*	green alga	Atlantic	1926	Wolf Creek (O)	R(A)
	Enteromorpha prolifera	green alga	Atlantic	1979	Lake St. Clair	Unknown
	Nitellopsis obtusa	green alga	Eurasia	1983	Lake St. Clair	S(BW)
Chrysophyceae	*Hymenomonas roseola*	coccolithophorid	Eurasia	1975	Lake Huron	S(BW)
Bacillariophyceae	*Actinocyclus normanii fo. subsalsa*	diatom	Eurasia	1938	Lake Ontario	S(BW)
	Biddulphia laevis	diatom	widespread	1978	Lake Michigan	S(BW)
	Cyclotella atomus	diatom	widespread	1964	Lake Michigan	S(BW)
	Chaetoceros hohnii	diatom	unknown	1978	Lake Huron	S(BW)
	Skeletonema potamos	diatom	widespread	1963	Toledo, Ohio (E)	S(BW)
	Skeletonema subsalsum	diatom	Eurasia	1973	Sandusky Bay (E)	S(BW)
	Stephanodiscus binderanus	diatom	Eurasia	1938	Lake Michigan	S(BW)
	Stephanodiscus subtilis	diatom	Eurasia	1946	Lake Michigan	S(BW)
	Thalassiosira guillardii	diatom	widespread	1973	Sandusky Bay (E)	S(BW)
	Thalassiosira lacustris	diatom	widespread	<1978	Lake Erie	S(BW)
	Thalassiosira pseudonana	diatom	widespread	1973	Ohio (E)	S(BW)
	Thalassiosira weissflogii	diatom	widespread	1962	Detroit River	S(BW)
	Diatoma ehrenbergii	diatom	widespread	1930s	Lake Michigan	S(BW)
	Cyclotella cryptica	diatom	widespread	1964	Lake Michigan	S(BW)
	Cyclotella pseudostelligera	diatom	widespread	1946	Lake Michigan	S(BW)
	Cyclotella woltereki	diatom	widespread	1964	Lake Michigan	S(BW)
Phaeophyceae	*Sphacelaria fluviatilis*	brown alga	Asia	1975	Gull Lake (M)	R(AQ), R(A)
	Sphacelaria lacustris	brown alga	unknown	1975	Lake Michigan	S(BW)
Rhodophyceae	*Bangia atropurpurea*	red alga	widespread	1964	Lake Erie	S(BW), S(F)
	Chroodactylon ramosum	red alga	Atlantic	1964	Lake Erie	S(BW)
Submerged Plants						
Marsileaceae	*Marsilea quadrifolia*	European water clover	Eurasia	<1925	Cayuga Lake (O)	R(D)
Cabombaceae	*Cabomba caroliniana*	fanwort	Southern U.S.	1935	Kimble Lake (M)	R(AQ), R(A)
Brassicaceae	*Rorippa nasturtium aquaticum*	water cress	Eurasia	1847	Niagara Falls (O)	R(C)
Haloragaceae	*Myriophyllum spicatum*	Eurasian watermilfoil	Eurasia	1952	Lake Erie	R(AQ), S(F)
Trapaceae	*Trapa natans*	water chestnut	Eurasia	<1959	Lake Ontario (T)	R(A), R(AQ)
Menyanthaceae	*Nymphoides peltata*	yellow floating heart	Eurasia	1930	Conneaut River (E)	R(A)
Hydrocharitaceae	*Hydrocharis morsus-ranae*	European frog-bit	Eurasia	1972	Lake Ontario	
R(AQ),R(D,S(F)						
Potamogetonaceae	*Potamogeton crispus*	curly pondweed	Eurasia	1879	Keuka Lake (O)	R(D), R(F)
Najadaceae	*Najas marina*	spiny naiad	Eurasia	1864	Onondaga Lake (O)	S(SB)
	Najas minor	minor naiad	Eurasia	1932	Lake Cardinal (E)	R(D)
Marsh Plants						
Chenopodiaceae	*Chenopodium glaucum*	oak leaved goose foot	Eurasia	1867	Onondaga Lake (O)	RH
Caryophylliaceae	*Stellaria aquatica*	giant chickweed	Eurasia	1894	Lake St. Clair	unknown
Polygonaceae	*Polygonum caespitosum var. longisetum*	bristly lady's thumb	Asia	1960	Ohio (E)	unknown
	Polygonum persicaria	lady's thumb	Eurasia	<1843	widespread	unknown
	Rumex longifolius	yard dock	Eurasia	1901	isle Royale (S)	R(C)
	Rumex obtusifolius	bitter dock	Eurasia	<1840	widespread	unknown

Continued

TABLE 4. Continued

Taxon	Species	Common Name	Origin	Date	Location	Mechanism
Brassicaceae	*Rorippa sylvestris*	creeping yellow cress	Eurasia	1884	Rochester, NY (O)	S(SB)
Primulaceae	*Lysimachia mmmularia*	moneywort	Eurasia	1882	central NY (O)	R(C)
	Lysimachia vulgaris	garden loosestrife	Eurasia	1913	central NY (O)	R(C)
Lythraceae	*Lyhrum salicaria*	purple loosestrife	Eurasia	1869	Ithaca, NY (O)	C, S(SB)
Onagraceae	*Epilobium hirsutum*	great hairy willow herb	Eurasia	1874	Ithaca, NY (O)	R(A), S(SB)
	Epilobium parviflorum	small flowered hairy willow herb	Eurasia	1966	Benzie Co., MI (M)	unknown
Apiaceae	*Conium macalatum*	poison hemlock	Eurasia	<1843	widespread	R(C)
Solanaceae	*Solarium dulcamara*	bittersweet nightshade	Eurasia	<1843	widespread	R(C)
Boraginaceae	*Myosotis scorpioides*	true forget-me-not	Eurasia	1886	central NY (O)	R(C)
Lamiaceae	*Lycopus asper*	western water horehound	Mississippi	1892	Lake Erie	R(A)
	Lycopus europaeus	European water horehound	Eurasia	1903	Lake Ontario	S(SB)
	Mentha gentilis	creeping whorled mint	Eurasia	1915	central NY (O)	R(C)
	Mentha piperita	peppermint	Eurasia	<1843	widespread	R(C)
	Mentha spicata	spearmint	Eurasia	<1843	widespread	R(C)
Scrophulariaceae	*Veronica beccabunga*	European brookline	Eurasia	1915	Monroe Co., NY (O)	S(SB)
Asteraceae	*Cirsium palustre*	marsh thistle	Eurasia	<1950	Lake Superior	unknown
	Pluchea odorata					
	var. succulents	salt-marsh fleabane	Atlantic	<1950	central NY (O)	unknown
	var. purpurescens	salt-marsh fleabane	Atlantic	1916	Lake Erie (T)	R(A)
	Solidago sempervirens	seaside goldenrod	**Atlantic**	1969	Chicago (M)	R(A)
	Sonchus arvensis	field sow thistle	Eurasia	1865	central NY	R(A)
	Sonchus arvensis var. glabrescent	smooth field sow thistle	Eurasia	1902	Ohio (E)	R(A)
Butomaceae	*Butomus umbellatus*	flowering rush	Eurasia	<1930	Detroit River (E)	S(SB)
Balsaminaceae	*Impatiens glandulifera*	Indian balsam	Asia	1912	Port Huron (H)	R(C)
Juncaceae	*Juncus compresses*	flattened rush	Eurasia	<1895	Cayuga Lake (O)	R(A)
	Juncus gerardii	black-grass rush	Atlantic	1862	Chicago	S(SB)
	Juncus inflexus	rush	Eurasia	1922	central, NY	unknown
Cyperaceae	*Carex acutiformis*	swamp sedge	Eurasia	1951	St. Joseph Lake (M)	unknown
	Carex disticha	sedge	Eurasia	1866	Belleville, Ontario (O)	S(SB)
	Carex flacca	sedge	Eurasia	1896	Detroit River	unknown
Poaceae	*Agrostis gigantea*	redtop	Eurasia	1884	Ontario (S)	R(C)
	Alopecurus geniculatus	water foxtail	Eurasia	1882	Lake Erie	R(C)
	Echinochloa crusgalli	barnyard grass	Eurasia	<1843	widespread	R(C), S(SB)
	Glyceria maxima	reed sweet-grass	Eurasia	1940	Lake Ontario	R(C), S(SB)
	Poa trivalis	rough-stalked meadow grass	Eurasia	<1843	widespread	R(C), S(SB)
	Puccinellia distans	weeping alkali grass	Eurasia	1893	Montezuma, NY (O)	S(SB), RH
Sparganiaceae	*Sparganium glomeratum*	bur reed	Eurasia	1936	Lake Superior	unknown
Typhaceae	*Typha angustifolia*	narrow leaved cattail	Eurasia	1880s	central NY (O)	C, R(A)
Iridaceae	*Iris pseudacorus*	yellow flag	Eurasia	1886	Ithaca, NY (O)	R(C)
Shoreline Trees and Shrubs						
Betulaceae	*Alnus glutinosa*	black alder	Eurasia	<1913	widespread	R(C)
Salicaceae	*Salix alba*	white willow	Eurasia	<1886	widespread	R(C)
	Salix fragilis	crack willow	Eurasia	<1886	widespread	R(C)
	Salix purpurea	purple willow	Eurasia	<1886	widespread	R(C)
Rhamnaceae	*Rhamnus frangula*	glossy buckthorn	Eurasia	<1913	Ontario	R(C)

APPENDIX B

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APPENDIX C

Web Sites on Great Lakes Nonindigenous Invasive Species

- ***American Society of Limnology and Oceanography***
  http://www.aslo.org/

  Provides information and updates on current topics. Additionally, registration for online use of *Limnology and Oceanography* journal is available**.**

- ***ANS Task Force***
  http://www.anstaskforce.gov/

  Provides information from the national ANS Task Force, including fact sheets, activities and accomplishments of the Task Force, reports and publications, meeting summaries, information on national meetings, state ANS management plans, and research.

- ***Biological Control Laboratory: University of Guelph***
  http://www.uoguelph.ca/~obcp/

  Catalogs purple loosestrife control strategies from Ontario and the Grand River Watershed. Contains references and links.

- ***Biological Invasions – Journal***
  http://www.wkap.nl/journalhome.htm/1387-3547

  Serves as homepage of the journal, *Biological Invasions*, providing abstracts and a searchable index of articles, along with subscription information and links to journals of related subjects.

- ***Canadian Coast Guard – Ballast Water Management***
  http://www.dfo-mpo.gc.ca/regions/central/Wiley/bw_index.html

  Outlines the responsibilities and programs of the Canadian Coast Guard in managing ballast water transfers.

- ***Cercopagis pengoi: Another Ponto-Caspian Invader in the Great Lakes***
  http://www.cs.uwindsor.ca/users/h/hughm/private/cercopagis.html

  Provides information on *Cercopagis pengoi*, including pictures, distribution maps, updates on spread and references.

- ***Chippewa/Ottawa Treaty Fishery Management Authority***
  http://home.northernway.net/~qitfap/

  Provides information on the activities and organization of the Chippewa/Ottawa Treaty Fishery

Management Authority.

- ***Cooperative Agriculture Pest Survey & National Agricultural Pest Information System's Purple Loosestrife Page***
  http://www.ceris.purdue.edu/napis/pests/pls/index.html

  Includes current news updates, fact sheets, distribution maps and links to other Internet sites on purple loosestrife.

- ***Flowering Rush Project: Department of Biology, Queen's University***
  http://biology.queensu.ca/floweringrush/

  Offers information on the flowering rush and the work being completed for the flowering rush project. Links and location information for the flowering rush are provided.

- ***Global Invasive Species Program***
  http://jasper.stanford.edu/GISP/home.htm

  Provides information on vectors of spread, educational efforts, ecological and economic consequences, early warning systems, current status, and assessment and best management practices. Information on terrestrial nonindigenous species is also emphasized.

- ***Great Lakes Commission – Great Lakes Panel on Aquatic Nuisance Species***
  http://www.glc.org/ans/anspanel.html

  Since 1991, the Great Lakes Panel on Aquatic Nuisance Species (ANS) has worked to prevent and control the occurrence of aquatic nuisance species in the Great Lakes. Their site features copies of the *ANS Update* newsletter, publications and policy position of the Panel, meeting summaries and upcoming events.

- ***Great Lakes Environmental Research Laboratory***
  http://www.glerl.noaa.gov/

  Offers synopses of current GLERL research and a broad data library. Provides links, publications, a description of facilities and searchable pages.

- ***Great Lakes Fishery Commission***
  http://www.glfc.org

  The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States in 1955. Their site features information on sea lamprey control, fishery management, publications and other materials, timely topics of interest, and images of sea lamprey and other Great Lakes fish. The site also features an extensive section of links to other pages of interest.

- ***Great Lakes Indian Fish and Wildlife Commission***
  http://www.glifwc.org/

Provides information on many different aspects of aquatic nuisance species in the Great Lakes, tribal hatchery and fishery updates, descriptions of treaties and treaty rights, regulations, scientific reports and links.

- ***Great Lakes Information Network – Invasive Species Page***
  http://www.great-lakes.net/envt/flora-fauna/invasive/invasive.html

  Provides an excellent overview of nonindigenous invasive species issues, focusing on exotic species in the Great Lakes region with pictures, profiles of select species, timely updates and general resources. GLIN also provides a wide selection of links to other Internet materials including ballast water information, educational materials, the text of relevant laws, publications, state management plans and task forces. Visitors can also view the 30-minute TV special, *Aquatic Invaders.*

- ***Great Lakes Institute for Environmental Research***
  http://webnotes1.uwindsor.ca:8888/units/glier/glier.nsf

  Details the research efforts and publications of the GLIER. Provides information on the staff and links to other pages of interest.

- ***Great Lakes Radio Consortium***
  http://www.glrc.org/

  Provides high-quality environmental news and in-depth coverage of issues concerning the Great Lakes. Viewers can listen to GLRC coverage, as well as offer comment. Links to related pages are provided.

- ***Great Lakes Sport Fishing Council***
  http://www.great-lakes.org/exotics.html

  Offers links to information on a variety of nonindigenous aquatic nuisance species in the Great Lakes. Other resources include information on laws and policies, newsletters and distribution maps.

- ***Great Lakes United***
  http://www.glu.org/

  Great Lakes United is an international coalition dedicated to preserving and protecting the Great Lakes - St. Lawrence River ecosystem. Their web site features documents; newsletters; and in-depth coverage of issues in five program areas: sustainable waters, habitat protection, clean production, healthy communities, and nuclear-free lakes.

- ***Hugh MacIsaac's Laboratory for the Study of Biological Invasions***
  http://www.uwindsor.ca:7000/biology/macisaac/pages/index.htm

  Contains information on projects involving *Echinogammarus* and *Corophium* amphipods, *Bythotrephes* water fleas; and *Cercopagis* water fleas. Images, links and several full-text online articles are provided.

- ***Illinois Department of Natural Resources***
  http://dnr.state.il.us/

  Provides searchable information on aquatic nuisance species programs in the state of Illinois and information on other activities of the Illinois DNR.

- ***Illinois Natural History Survey: Vegetation Management Guidelines for Purple Loosestrife***
  http://www.inhs.uiuc.edu/edu/VMG/ploosestrife.html

  Contains descriptions, control recommendations, failed techniques and reference materials for controlling the spread of purple loosestrife.

- ***Illinois Natural History Survey: Update on Zebra Mussels and Native Unionids in the Illinois River***
  http://www.inhs.uiuc.edu/chf/pub/news/hav2.html

  Provides an update on zebra mussel activities in the Illinois River, discussing control and monitoring techniques used in this unique area**.**

- ***Indiana Department of Natural Resources***
  http://www.state.in.us/dnr/

  Provides searchable information on ANS programs in the state of Indiana, and other activities of the Indiana DNR.

- ***International Association for Great Lakes Research***
  http://www.iaglr.org/

  Provides information and fact sheets on each of the Great Lakes, timely topics of interest and research publications. The site includes abstracts and ordering information for the *Journal of Great Lakes Research*.

- ***International Joint Commission***
  http://www.ijc.org/ijcweb-e.html

  Offers publications and reports on aquatic nuisance species in the Great Lakes and other areas of Canada and the United States. The site documents binational efforts on research, monitoring and control.

- ***Invasive Plants of Canada Project***
  http://infoweb.magi.com./~ehaber/ipcan.html

  Offers current updates on invasive plants, including information on purple loosestrife and European frog-bit (compiled by Alan Dextrase, Ontario Ministry of Natural Resources).

- ***MIT Sea Grant***
  http://web.mit.edu/seagrant/index.html

The MIT Sea Grant site offers a searchable, online publication directory with publications dating back to 1971. The site also provides educational materials and a list of research projects currently pursued by MIT Sea Grant.

- ***Michigan Department of Environmental Quality – Office of the Great Lakes***
  http://www.deq.state.mi.us/ogl

  Features a selection of materials on exotic species control. Available on the web site are several documents, including Michigan's Nonindigenous Aquatic Nuisance Species (ANS) State Management Plan, the ANS State Management Plan Progress Report, and an ANS Handbook for Government Officials.

- ***Michigan Sea Grant – Zebra Mussel/Aquatic Nuisance Species Office***
  http://www.msue.msu.edu/seagrant/sgezmans.html

  Contains several helpful features, including an extensive graphic library containing approximately 100 images available for loan or purchase. Also included are the Purple Pages, documenting the Purple Loosestrife Control Project at Michigan State University. This section features educational material for students from kindergarten to12th grade and a purple loosestrife control handbook. Exotic species publications are also available on the web site.

- ***Minnesota Department of Natural Resources***
  http://www.dnr.state.mn.us/

  Provides information on aquatic nuisance species programs in the state of Minnesota and other activities of the Minnesota DNR.

- ***Minnesota Sea Grant***
  http://www.d.umn.edu/seagr

  Offers information and educational materials on exotic species, including the exotic flowering rush, round goby, ruffe and zebra mussel ID cards, publications, teaching materials and a field guide to aquatic exotic plants and animals.

- ***National Agricultural Pest Information System (NAPIS): Pest Information***
  http://www.ceris.purdue.edu/napis/pests/index.html

  Allows the user to search for information about a variety of pests and nonindigenous species that impact agricultural practices in the United States.

- ***National Aquatic Nuisance Species Clearinghouse***
  http://www.entryway.com/seagrant/

  Provides access to North America's most extensive technical library of publications related to the spread, biology, impacts and control of zebra mussels and other important aquatic nuisance species. Containing a database of searchable information, the clearinghouse offers information on a variety of aquatic nuisance species.

- ***National Park Service, Plant Conservation Alliance's Alien Plant Working Group***
  http://www.nps.gov/plants/alien/

  Provides a compiled national list of invasive plants infesting natural areas throughout the United States; background information on the problem of invasive species; illustrated fact sheets that include plant descriptions, native range, distribution and habitat in the United States; management options, suggested alternative native plants; and selected links to relevant people and organizations.

- ***New York State – Department of Environmental Conservation***
  http://www.dec.state.ny.us/

  Provides information on aquatic nuisance species programs in the state of New York and other activities of the New York DEC.

- ***Northeast-Midwest Institute – Biological Pollution: Aquatic Invasive Species***
  http://www.nemw.org/biopollute.htm

  Offers an overview of National Invasive Species Act (NISA) implementation, updates on the Great Lakes Ballast Technology Demonstration Project, Northeast-Midwest Institute policy analysis and reports, relevant links, and information and outreach.

- ***Northeast Sea Grant's Aquatic Exotics News***
  http://www.ucc.uconn.edu/~wwwsgo/aen.html

  Provides updates from the Northeast Sea Grant programs on the spread of nonindigenous aquatic nuisance species. Although not focused exclusively on the Great Lakes region, the site does feature information about the spread of exotics into the area.

- ***Ohio Department of Natural Resources***
  http://www.dnr.state.oh.us/

  Provides information on aquatic nuisance species programs in the state of Ohio and other activities of the Ohio DNR.

- ***Ohio Sea Grant and Lake Erie Programs***
  http://www.sg.ohio-state.edu/

  Provides a clearinghouse for information on exotic species in the Lake Erie region, searchable publications, educational and outreach materials, and links to the Great Lakes Aquatic Ecosystem Research Consortium and Center for Lake Erie Research.

- ***Ontario Federation of Anglers and Hunters***
  http://www.ofah.org/invading/invading.htm

  Contains information on a variety of nonindigenous aquatic species and advice for preventing their spread.

- ***Ontario Ministry of Natural Resources***
  http://www.mnr.gov.on.ca/

  Provides information on aquatic nuisance species programs in Ontario, and other activities of the Ontario MNR. Available in French and English.

- ***Pennsylvania Department of Environmental Protection***
  http://www.dep.state.pa.us/

  Provides information on aquatic nuisance species programs in the Commonwealth of Pennsylvania and other activities of the Pennsylvania DEP.

- ***Purple Loosestrife InfoCenter, developed by Manitoba Purple Loosestrife Project***
  http://www.ducks.ca/purple/

  Contains newsletters and updates, research abstracts, brochures, information on biological control, resources materials, pictures, answers to frequently asked questions, and links to other resources on purple loosestrife.

- ***Quebec's Aquatic Nuisance Species Web Site***
  http://www.fapaq.gouv.qc.ca/fr/faune/nuisibles/index.htm

  Details the extent of the aquatic nuisance species problem around Quebec and describes current monitoring and enforcement efforts (available in French only).

- ***Ruffe Control Program***
  http://www.fws.gov/r3pao/ashland/ruffe/ruf_cont.html

  Contains a copy of the Ruffe Control Program as submitted to the Aquatic Nuisance Species Task Force. It discusses solutions to ruffe control through population reduction, ballast water management, population investigation surveillance, fish community management, education and bait fish management. It contains sections on the Chicago Sanitary and Ship Canal, research needs and an extensive list of references.

- ***Sea Grant Nonindigenous Species Site – Zebra Mussel and Other Aquatic Nuisance Species***
  http://www.sgnis.org/

  Provides an extensive site that is simple and searchable, offering a wide variety of information on nonindigenous aquatic species. The site features several products available for distribution, such as bibliographies, education materials (kindergarten to university level), maps, newsletters, publications, research, training material and videos. Additionally, the site features a large graphic library of exotic species slides and links to nonindigenous aquatic species information designed for kids.

- ***University of Minnesota: Eurasian Watermilfoil Biocontrol Web Site***
  http://www.fw.umn.edu/research/milfoil/milfoilbc.html

  Contains information on the control of Eurasian watermilfoil, along with many references.

- ***U.S. Army Corps of Engineers, Great Lakes Regional Headquarters – Nuisance and Exotic Species***
  http://www.lrd.usace.army.mil/gl/exotic.htm

  Provides information on the Corps' activities promoting the health of the Great Lakes ecosystem. These programs include the restoration of environmental quality, Great Lakes Remedial Action Plans, planning assistance to states, the Chicago Sanitary and Ship Canal Dispersal Barrier, the aquatic plant control research program, and the zebra mussel research program.

- ***U.S. Coast Guard – Ballast Water Management Program***
  http://www.uscg.mil/hq/g%2Dm/mso4/contents.htm

  Details the U.S. Coast Guard's efforts to manage ballast water, including current news, a program description, briefs and talks, IMO documents, their field program, images, ballast water reporting forms, and ballast water regulations.

- ***U.S. Department of Agriculture – Animal and Plant Health Inspection Service***
  http://www.aphis.usda.gov/

  Contains information on the efforts of APHIS to detect and monitor animal and plant diseases in this country and to combat certain domestic animal diseases and plant pests. Of particular interest under "hot topics" is a site on the Asian longhorned beetle.

- ***U.S. Environmental Protection Agency – Great Lakes National Program Office***
  http://www.epa.gov/glnpo/

  Contains reports on monitoring, human health, ecology, sedimentation, pollution prevention, maps of the area and other program information.

- ***U.S. Fish and Wildlife Service – Invasive Species Program***
  http://invasives.fws.gov/

  Includes extensive information on many topics of interest, including current hot topics on invasive species, the Presidential Executive Order; mandates and legislation, the USFWS Director's priorities; the national strategy for invasive plant management, threat assessment, impacts to the refuge system and other areas, control and prevention efforts, pest management; and outreach and education.

- ***U.S. Geological Survey – Biological Resources Division***
  http://www.nbs.gov/

  Provides extensive information on biological resources, including science, news and information, partnerships and frequent updates on areas of interest. Fact sheets and research information are also included.

- ***U.S. Geological Survey – Invasive Species***
  http://www.emtc.nbs.gov/invasive_species/invasives.html

Provides information on a variety of exotic aquatic species.

- ***Weed Feeders, Biological Control: A Guide to Natural Enemies in North America***
  http://www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/wdfdrtoc.html

  Includes a searchable list of biological control agents for a variety of species, including the purple loosestrife.

- ***Wisconsin Department of Natural Resources***
  http://www.dnr.state.wi.us

  Provides information on aquatic nuisance species programs in the state of Wisconsin, and other activities of the Wisconsin DNR.

- ***Wisconsin Sea Grant – Zebra Mussels and Other Nonindigenous Species***
  http://www.seagrant.wisc.edu/greatlakes/GLnetwork/exotics.html

  Provides detailed information on several different aquatic species, including a link to Michigan Sea Grant's aquatic nuisance species graphic library.

APPENDIX D - Great Lakes Nonindigenous Invasive Species Workshop: Agenda and Participant Listing

Great Lakes Nonindigenous Invasive Species Workshop
Wednesday, October 20, 1999 1:00 p.m. to 5:00 p.m. (CDT)
Thursday, October 21, 8:00 a.m. to 1:00 p.m. (CDT)

U.S. Environmental Protection Agency and Great Lakes Commission
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77 W. Jackson Boulevard
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FINAL AGENDA

Wednesday, Oct. 20

1:00 p.m.	**Welcome and Introduction**	**Gary Gulezian,** Director, U.S. EPA, Great Lakes National Program Office
	Workshop Overview and Objectives	**Marc Tuchman,** U.S. EPA, Great Lakes National Program Office and **Karen Rodriguez**, U.S. EPA, Great Lakes National Program Office
1:20 p.m.	**State of Affairs on Nonindigenous Invasive Species in the Great Lakes Basin**	Moderator: **Michael Donahue**, Great Lakes Commission
	Overview of Briefing Paper for Great Lakes Nonindigenous Invasive Species Workshop	**Kathe Glassner-Shwayder,** Great Lakes Commission
1: 45 p.m.	**Nonindigenous Aquatic Nuisance Species** • Ecological Overview • Management Issues	**John Gannon,** U.S. Geological Survey, Great Lakes Science Center Susan Jerrine Nichols, U.S. Geological Survey, Great Lakes Science Center (co-author)
2:30 p.m.	**Nonindigenous Terrestrial Noxious Species** • Ecological Overview • Management Issues	**Randy Westbrooks**, U.S. Department of Agriculture, Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW)
3:30 p.m.	**Break**	
3:45 p.m.	**Prevention of Nonindigenous Species Introductions and Spread**	**Allegra Cangelosi,** Northeast Midwest Institute **Jay Rendall,** Minnesota DNR
5:00 p.m.	**Adjourn for the Day**	

Thursday, Oct. 21

8:00 a.m .	**State of Affairs on Control, Detection and Monitoring, and Education/Outreach**	Moderator: **Michael Donahue**
	Overview and Objectives	**Michael Donahue**
8:15a.m.	**Control of Nonindigenous Species**	**Kelly Kearns,** Wisconsin DNR **Tom Busiahn,** U.S. Fish and Wildlife Service
9:15 a.m.	**Detection and Monitoring of Nonindigenous Species**	**Don Schloesser**, U.S. Geological Survey, Great Lakes Science Center **Tom Nalepa,** Great Lakes Environmental Research Lab, NOAA **Noel Pavlovic,** U.S. Geological Survey **Miles Falk,** Great Lakes Indian Fish & Wildlife Commission
10:15 a.m.	**Break**	
10:30 a.m.	**Education/Outreach on Nonindigenous Species Issues**	**Doug Jensen,** Minnesota Sea Grant **Tim Sinnott,** New York Depart. of Env. Conservation
11:30 a.m.	**Discussion on Prevention, Control, Detection and Monitoring, and Education/Outreach**	**Kathe Glassner-Shwayder**, Moderator **Workshop Participants**
12:30 p.m.	**Wrap Up, Closing Remarks and Next Steps**	**Kathe Glassner-Shwayder, Marc Tuchman, Karen Rodriguez**
1:00 p.m.	**Adjourn**	

Great Lakes Nonindigenous Invasive Species Workshop: *Participant Listing*

October 20-21, 2000
Chicago, Illinois

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