Biological Pollution of the Great Lakes:

The Nonindigenous Aquatic Species Issue

Fact Sheet

by

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Introduction

An extraordinary form of pollution is impacting the Great Lakes Basin but is taking place mostly out of sight of the general public which lives, works and plays on and around the lakes. This pollution has nothing to do with industrial facilities spewing wastes into the air or the water, nor with hazardous waste dumps, power plants, sewage discharges, nor any of the other "culprits" which are usually associated with pollution of the lakes. This pollution is in the form of non-native organisms which have been introduced to the lakes, and the lands around them, by either natural or human-mediated mechanisms. These species run the gamut from plants, such as purple loosestrife and poison hemlock, to familiar animals, such as common carp and zebra mussels, to pathogens, such as "whirling" disease, which impact native and non-native organisms alike. These non-native species have caused dramatic changes to the Great Lakes ecosystem. At the time of writing of this publication, there are believed to be 162 non-native species resident in the Great Lakes Basin.

This biological pollution is referred to by many names: exotic species, non-native or nonindigenous species, aquatic nuisance species, and invasive species. In this publication, I will use the term "nonindigenous" synonymously with "non-native," defined as "those [species] that have been transported by human activities – intentionally or unintentionally – into a region in which they did not occur in historical time and are now reproducing in the wild" (Carlton 2001). I will also use the term "invasive species" as meaning ". . . an alien [non-native] species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Ex. Order 13112). It should be noted that non-native is not synonymous with invasive, the latter involving an element of harm not necessarily implied in the former. It is also possible for some species to be introduced into a new habitat through such natural means as interbasin flooding and by swimming from one waterbody to another. To be listed in this publication, a non-native species must be reproducing in self-sustaining populations in their new Great Lakes environment. Organisms which have failed to establish self-sustaining populations (such as the occasional flounder or octopus which finds its way into the St. Lawrence River or the Great Lakes and then dies) are not included in this publication. Aquatic invasive species are often

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referred to as “aquatic nuisance species.”

The Making of an Invasive Species

These organisms share some or all of a number of biological characteristics:

- high abundance in their native range (where they are “picked up” for transit to the Great Lakes);
- high fecundity rates, allowing them to produce more offspring that survive than die once introduced to a new environment;
- a short generation time, with offspring maturing to a reproduction-capable age very quickly (again, providing a large number of offspring in the receiving habitat);
- polyphagous feeding habits (they can utilize more than one food, allowing them to out-compete native species which might rely on a single food source);
- an ability to occupy diverse habitats (as opposed to many native species which have evolved to occupy only a narrowly defined habitat which, if degraded, can have negative effects on the population);
- high genetic variability (allowing for “plasticity” in adapting to new environments or changes in existing environments);
- and, proximity to a transmittal vector (if an organism does not exist in a location where it can be acquired and moved by a transmittal mechanism, that organism will not be introduced to North America).

Non-native species have been called “biological pollution” due to their ability to negatively impact the ecosystem and the native populations of the flora and fauna that it supports. The combined effect of non-native species has been to alter the Great Lakes food web, as well as to alter trophic levels from the lowliest plankton to the top predatory fishes. Nonindigenous aquatic species can have catastrophic impacts by displacing native species, sometimes to the point of local extinction (extirpation), thereby reducing biological diversity. For example, several native species of mussels have been extirpated in Lake St. Clair as a result of the zebra mussel invasion, and native mussel populations in some areas of Lake Erie are jeopardized, as well. As a whole, the impacts of non-native species introductions may be as great, if not greater, a threat to the Great Lakes ecosystem than the impact of habitat loss. Some species, such as the sea lamprey and the zebra mussel, have had significant economic as well as ecological impacts. Nonindigenous aquatic species in the Great Lakes include fishes, mollusks, crustaceans, other invertebrates, diatoms, aquatic and shoreline plants, and pathogens.

History of Great Lakes Invasions

This biological pollution is not new to the Great Lakes Basin. Natural introductions of species not native to the Basin have been occurring since the North American glaciation disrupted widespread drainage patterns and formed the Great Lakes (about 12,000 years ago). The Great Lakes ecosystem is, therefore, quite young in geologic terms, and the biological communities in the lakes are the result of post-glaciation naturally-mediated invasions from drainages around the lakes. It can be hypothesized that the Native Americans who settled around the lakes were likely responsible for the movement of plants and animals from lake to lake prior to the 17th century exploration of the Great Lakes region by the French. We therefore cannot make

a definitive judgement of the original, post-glaciation composition of the lakes' biological communities. When discussing nonindigenous species introductions to the Great Lakes, most scientists use the start of the post-Columbian European settlement of the Basin as a reference or base line date.

Anthropogenic (human-influenced) introductions have been taking place since the region began to be settled by Europeans (what some have referred to as the greatest biological invasion since the ice age), carried here by accident and by design as the Europeans tried to remake the region into a facsimile of home. As the amount of human development in the region increased in the 1800s and 1900s, the age of canal and railroad building, so too did the number and frequency of non-native species introductions. More than one-third of the nonindigenous aquatic species in the Great Lakes have been introduced in the years since the opening of the St. Lawrence Seaway in the late-1950s (Mills *et al*. 1991).

During the early years of European colonization of the Great Lakes Basin, Niagara Falls served as an impenetrable barrier to the dispersal of many non-native species which had been introduced into the Lake Ontario Basin. The construction of early canals dissolved barriers between basins, allowing for the interbasin migration of species. The Erie Canal opened in 1825 and provided direct water connection from the Hudson River into Lakes Erie and Ontario. At the canal's opening, New York Governor DeWitt Clinton, in what proved to be a prophetic action, dumped a cask of Lake Erie water, carried by the first east-bound canal boat, into NY Harbor; west-bound boats carried to Lake Erie casks of Atlantic Ocean water, foreshadowing later, large-scale ballast transfers.

Traffic through the Erie Canal was in the form of canal boats which plied the waters of the canal but which, typically, did not sail into the canal from other waters since the canal could not carry ocean-going ships. As such, the canal provided a means for nonindigenous aquatic species to enter the Great Lakes directly by swimming through (or being carried in currents in) the canal, or as unintentional stowaways in or on the canal boats. The first known post-Columbian introduction was the sea lamprey (*Petromyzon marinus*) [Fig. 1], which one hypothesis posits entered Lake Ontario sometime in the 1830s via canals (it is also possible that the lamprey is a relic of pre-glacial populations). The Welland Canal, opened in 1829 and enlarged in 1919, provided a path for small ships which stayed within the confines of the Great Lakes ("lakers") from Lake Ontario around Niagara Falls into Lake Erie and served as a major pathway for nonindigenous species movements. Later, in the mid-1800s, the first St. Lawrence River canal system was completed which allowed small ocean-going vessels to sail upstream from Quebec into Lake Ontario. The Welland Canal allowed transit of these vessels (and any non-native species they might be carrying) upstream from the lower St. Lawrence and the Atlantic Ocean into the Upper Great Lakes. Far later, the construction of the St. Lawrence Seaway in 1959 provided a major direct pathway into the Great Lakes for large, international, ocean-going ships to introduce to the Great Lakes invasive aquatic species from around the globe.

Fig. 1 Sea lamprey

The opening of the St. Lawrence Seaway indirectly allowed ships to deliver organisms from all over the world into the Great Lakes. However, access alone cannot account for the dramatic increase in nonindigenous aquatic species in the Great Lakes. It is believed that a number of factors, combined with the physical existence of the Seaway, are acting synergistically to allow

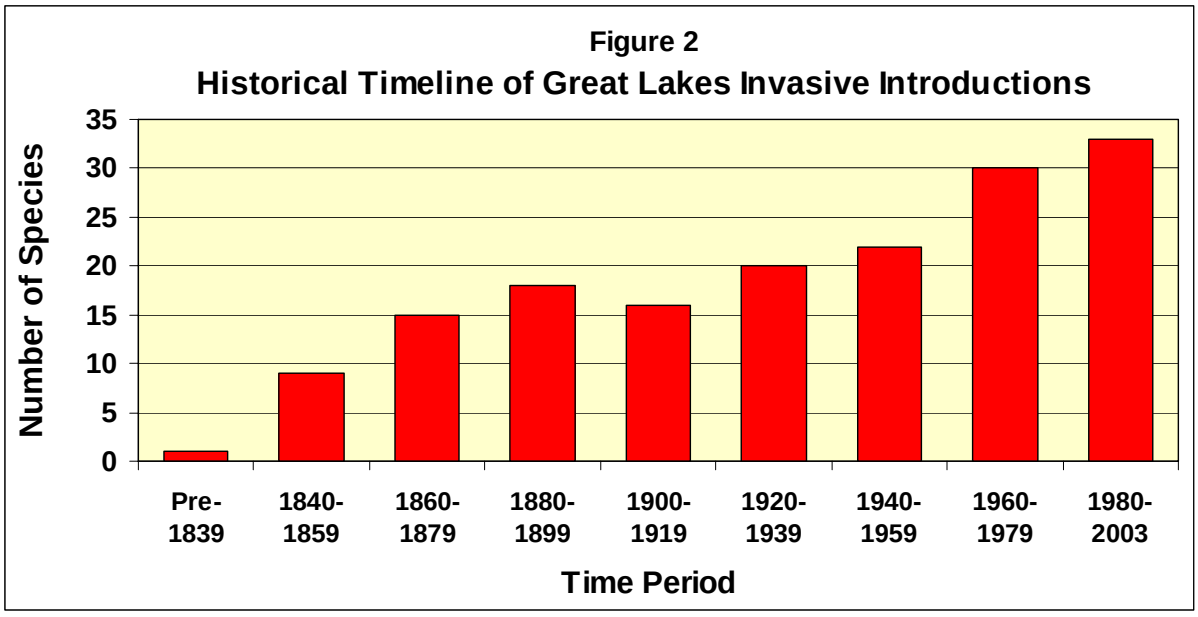
for this jump in successful invasions.

- It is believed that natural selection of species in the native (or source) range (which have, in many instances, been very polluted and degraded since the advent of the Industrial Revolution and the two World Wars) has resulted in a number of robust organisms having the characteristics listed earlier in this paper. It therefore becomes more likely that species being transported to the Great Lakes are ones which have a good chance of survival upon arrival.
- Recent improvements in the water quality of invaders' native ranges has resulted in there being many more live organisms in those source waters to enter the "pipeline."
- Improvements in technology and ship building have resulted in transoceanic vessels having shorter transit times on the way to North America, resulting in greater survival rates of organisms being transported.
- Increases in transoceanic shipping since the late-1950s, coupled with larger ships have resulted in more ballast water from foreign environments being discharged into the Great Lakes, along with whatever organisms might be entrained in those ballast waters.
- There have been dramatic improvements in the water quality in the Great Lakes receiving waters since the passage of the Clean Waters Act, resulting in a more hospitable environment for the newly introduced organisms.

The bottom line: more viable organisms surviving their introductions into the lakes.

A summary of time periods of invasion follows [Fig. 2]. Pre-1839 (the period from the start of European colonization through the early canal and railroad building period); 1840-1859 (encompasses the heyday of canal building, including the early St. Lawrence River canal

Figure 2



system, and the linking of the Great Lakes to the Atlantic Coast by railroads);1860 - 1879; 1880 - 1899 (the start of the transition from solid ballast to ballast water, early intentional stocking for "fishery enhancement"); 1900 - 1919 (more ships using ballast water than solid ballast, larger ships able to enter Great Lakes through improved and enlarged canal system, continued "fishery enhancement"); 1920 - 1939 (most ships now using ballast water); 1940 - 1959 (includes post-WWII increase in international shipping, pre-St. Lawrence Seaway);

1960 - 1979 (captures first 20 years after the opening of the St. Lawrence Seaway, international ships getting larger, transit times shorter); 1980 - present (greatest amount of international shipping, shortest transit times, captures time period of large grain sales from Great Lakes region to Soviet Union region [many cargo ships arriving in Great Lakes carrying large amounts of ballast instead of industrial cargo]).

Vectors of Introduction

Canal boats transiting the Erie Canal and New York State Barge Canal system, as well as the early St. Lawrence River canal system used solid ballast to keep the boats stabile when not fully loaded with cargo. This ballast was usually in the form of sand, rocks, soil, mud, or other solid debris loaded into the boats at whatever port they last off-loaded cargo. When the boat next on-loaded cargo, some or all of the ballast would be thrown overboard at special ballast dumping locations along the canal where the cargo was being loaded. Many sorts of plants and plant parts or seeds from which whole plants could later grow, as well as invertebrate animals, were transported unwittingly in such solid ballast. Non-native plants could also have been transported in the large amounts of fodder and bedding materials canal boats carried for the mules, draught horses and oxen used to pull the boats along the towpath. Some examples of the species believed to have been introduced into the Great Lakes Basin via solid ballast and fodder/bedding vectors include: the flowering rush (*Butomis umbellatum*), sedge (*Carex flacca*), purple loosestrife (*Lythrum salicaria*) [Fig. 3] and yellow flag iris (*Iris pseudacorus*). Several invertebrates believed to have been introduced in this manner include: the faucet snail (*Bithynia tentaculata*) and the European valve snail (*Valvata piscinalis*). It is possible that species not listed in this paper were also brought into the Great Lakes Basin in this manner but are considered as being indigenous because such introductions took place before biological surveys were performed to establish a native/non-native baseline and were mistakenly considered to have been native if they were already in place as self-sustaining populations at the time of the surveys. Later introductions took place via ballast water discharged from international ships entering the lakes through the St. Lawrence Seaway. The most well-known of these species is *Dreissena polymorpha*, the zebra mussel [Fig. 4].

Fig. 3
Purple loosestrife

Fig. 4
Zebra mussels

Some introductions of nonindigenous aquatic plants and animals, however, have no links to canals or shipping. Many species entered the Great Lakes through such vectors as the release of aquarium pets, which many aquarium owners feel is a more humane end to their water pets than flushing, dumping in the trash or feeding to the family cat (Oriental mystery snail, *Cipangopaludina chinensis malleata*); accidental releases from aquaculture facilities (pink salmon, *Orcorhynchus gorbuscha*); spilled bait buckets which contained nonindigenous baitfish species (rudd, *Scardinius erythrophthalmus*); intentional releases for fishery development but which proved to be monumental environmental mistakes, such as the common carp (*Cyprinus carpio*) [Fig. 5]; and, intentional “fishery enhancement” activities, such as the stocking of Pacific salmonids (Chinook,

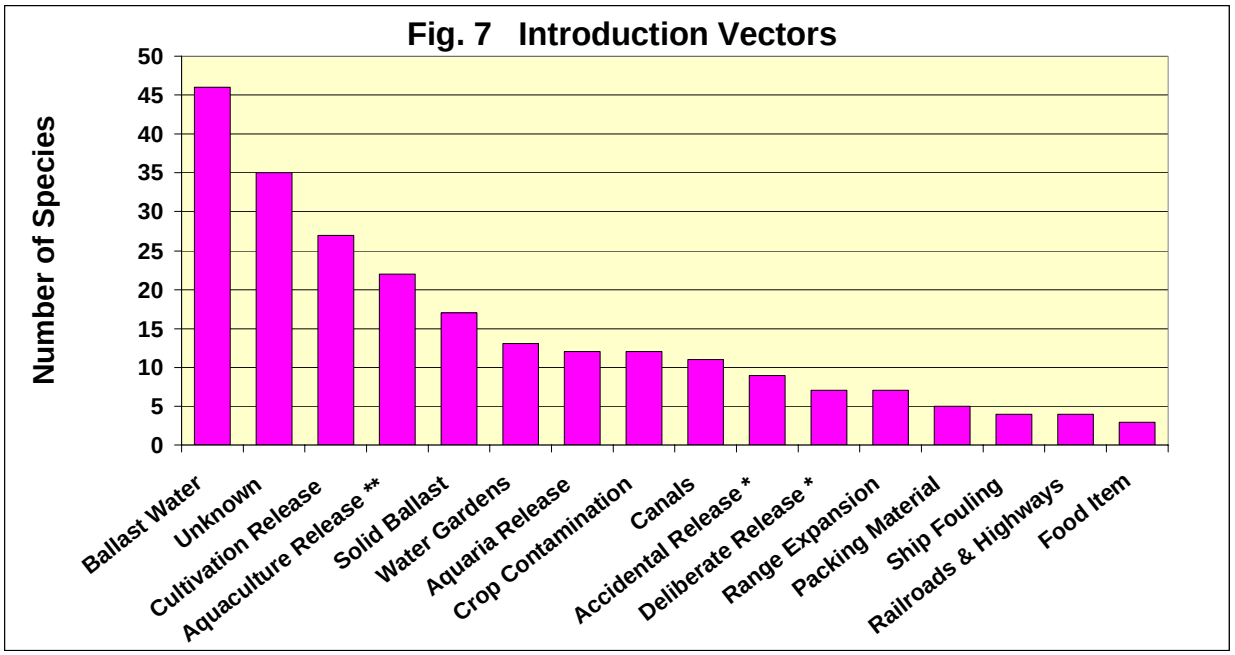

Fig. 5 Carp

Orcorhynchus tshawtscha).

Many plant species growing in wet areas throughout the Great Lakes Basin, such as peppermint (*Mentha piperita*), watercress (*Rorippa nasturtium aquaticum*), redtop (*Agrostis gigantea*), and black alder (*Alnus glutinosa*) were introduced to the Basin unintentionally as escapees from cultivation (it is also probable that purple loosestrife was introduced into many areas as a result of escape from cultivation). Accidental releases from ornamental water gardens, such as water chestnut (*Trapa natans*) [Fig. 6] have also contributed a number of invasive species to the Great Lakes Basin.

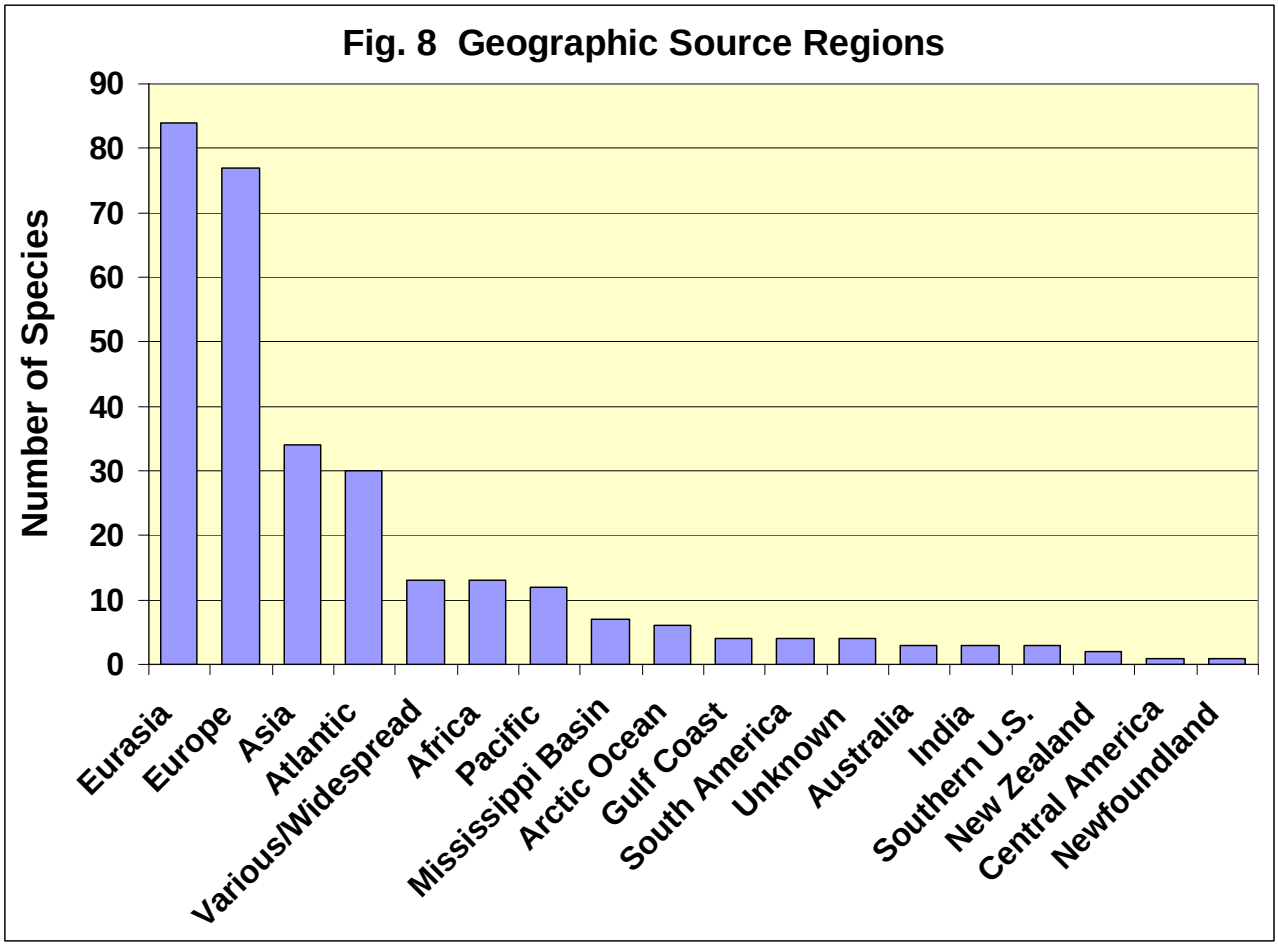

Fig. 6 Water chestnut

Regardless of whether different Great Lakes stakeholders consider some of these introductions beneficial, benign or detrimental, introductions of nonindigenous aquatic species have all contributed to the overall artificiality of the modern Great Lakes ecosystem. A summary of the relative importance of the various introduction vectors is shown in Figure 7 (the total is greater than 162 as a result of some species having multiple potential introduction vectors).



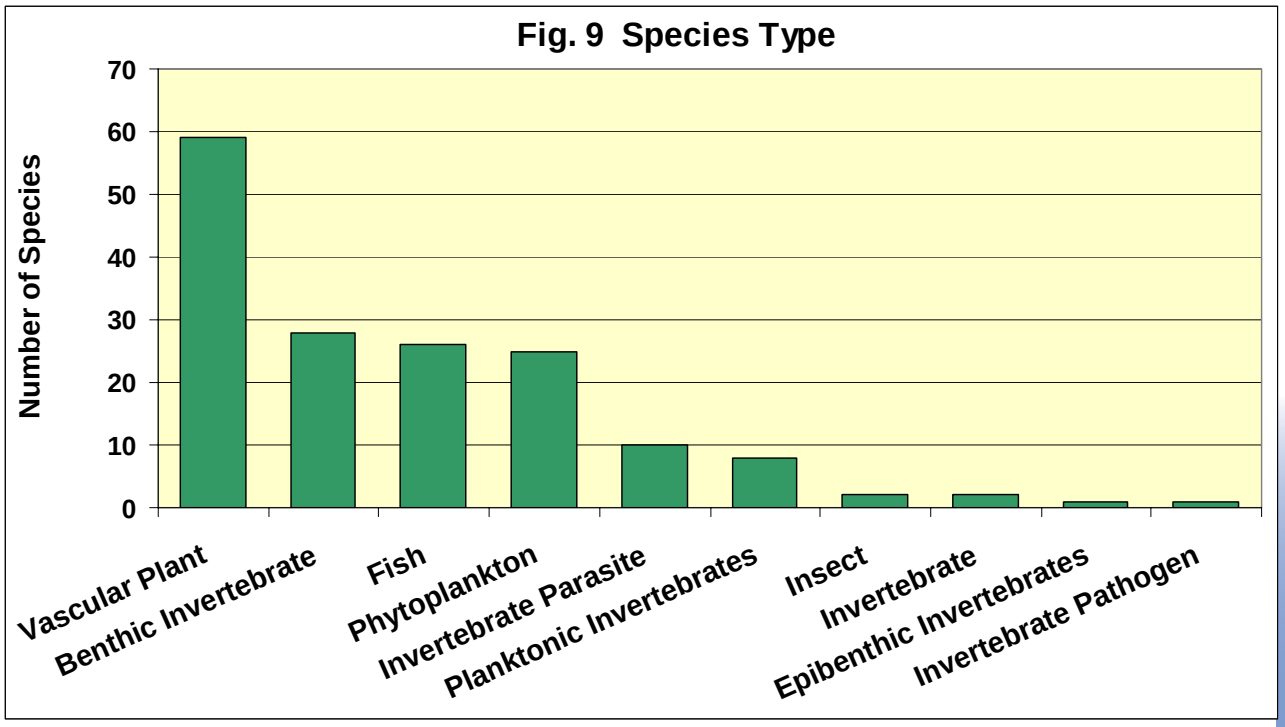
Source Regions for Great Lakes Invasive Species

These species have entered the Great Lakes from about 18 different source regions. The earliest introductions were from the area of Europe as colonization of North America progressed. Later on, as settlers began to come from areas other than just Europe, we saw Asia and Eurasia contribute an increasing number of species. With the advent of international shipping and ballast water dumping, as well as air travel from around the world, other regions began to contribute their biological specimens, as well. The current summary of source regions is shown in Figure 8 (the total of all regions is greater than 162 due to overlap and multiple source regions for many of the species).



Types of Great Lakes Non-Native Species

As one can see from the discussion of the various species which were introduced by various vectors, the range of invader types is quite varied. The breakdown by species type is summarized in Figure 9.



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Resources

For more information on Great Lakes and other aquatic invasive and aquatic nuisance species, log on to the website of the National Aquatic Nuisance Species Clearinghouse at www.aquaticinvaders.org. To learn more about invasive species in general, check out the U.S. federal government's premier invasive species website, www.invasivespecies.gov.

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Photo Credits

Figure 1. Sea lamprey: NYS Department of Environmental Conservation
Figure 3. Purple loosestrife: Robert H. Mohlenbrock, @ USDA-NRCS PLANTS Database / USDA SCS. 1989
Figure 4. Zebra mussels: Scott Camazine. NY Sea Grant
Figure 5. Common carp: Native Fish Conservancy
Figure 6. Water chestnut: Alfred Colfrancesco, US Army Corps of Engineers

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