Impact of non-indigenous species on the ecosystem of the Laurentian Great Lakes

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Nonindigenous species have become major components of the fish, plankton, and benthic communities of the Saint Lawrence Great Lakes. For many years it was recognized that nonindigenous fishes had a major impact on native fishes. More recently, a number of studies have shown that the exotic species can and do have demonstrable impact on the physics, chemistry, and biology of the Great Lakes ecosystems.

The sea lamprey, *Petromyzon marinus*, had a major impact on the Great Lakes fish communities and the fisheries (Hartman 1988). It severely and rapidly impacted populations of larger fishes, i.e., lake trout (*Salvelinus namaycush*); whitefish *(Coregonus clupeaformis)* burbot (*Lota lota)* and chubs (*Coregonus* spp.). Populations of lake trout collapsed in Lakes Huron, Michigan, and Superior. The collapse of the lake trout population in Lake Michigan occurred very rapidly (Fig. 1). Populations of *Coregonus artedii*, the lake herring, also declined, but it is likely that populations of this coregonid was impacted by two other non-indigenous species, the smelt, *Osmerus mordax*, and the alewife, *Alosa pseudoharengus*. The lake herring populations declined as smelt populations increased, and increased when smelt populations were low in Lake Michigan (Fig. 2). The additional competition from the alewife seems to have reduced lake herring stock to a very low level in Lakes Huron and Michigan.

The demise of the top predators in the upper lakes as well as the collapse of coregonid populations provided favorable conditions for

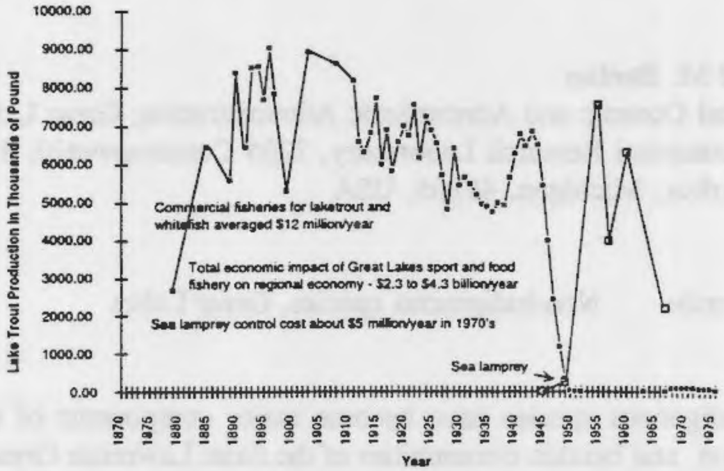

Fig. 1. *Commercial production of lake trout in Lake Michigan, 1879-1970 (Lake trout solid squares, data from Baldwin et al. 1979, sea lamprey open squares).*

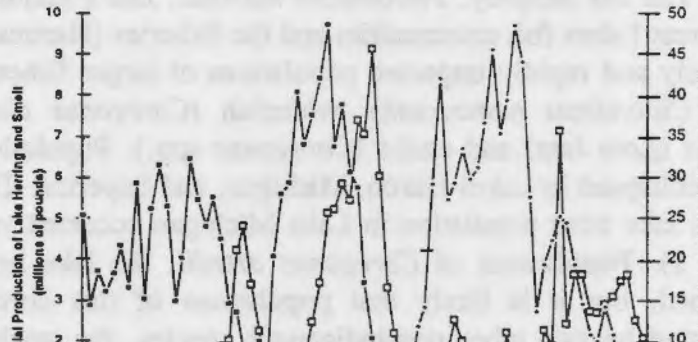

Fig. 2. *Commercial production of alewife (diamond), lake herring (solid square), and smelt (open square) in Lake Michigan (data from Baldwin et al. 1979).*

the alewife (Hartman 1988). Once established in lakes Huron and Michigan, the alewife populations exploded, and within a few years it was a dominant species. This planktivorous fish apparently brought about changes in the zooplankton community of Lake Michigan (Wells 1970). Large planktonic Crustacea decreased in abundance. Also, the size of *Daphnia* decreased when alewife were abundant, but subsequently regained a larger size when alewife numbers decreased.

Major changes have been observed in the ecosystems of western Lake Erie and Saginaw Bay, Lake Huron since the invasion of the zebra mussel (*Dreissena polymorpha*). Zebra mussel populations were first observed in western Lake Erie in the islands in 1988 and in Saginaw Bay in 1990. The initial change was a large increase in water clarity. The long-term average Secchi disc depth was around 1.2 m, but the depth increased to over 2.0 m in the 1990s (Fig. 3). Analysis of the diatom data showed that diatom abundances had declined by 86 percent (Holland 1993). The increased water clarity has favored the growth of aquatic macrophytes. The concentrations of nutrients changed pre- and post-zebra mussel (Holland *et al.* 1995). Ammonium, nitrate, soluble reactive phosphorus, and silica increased. Total phosphorus concentrations remained the same. The ammonium increase was probably due to excretion by the mussels. Increases in the other nutrients were likely a consequence of fewer algae removing the nutrients. The zooplankton has decreased, especially the copepods.

We observed a large bloom of a blue-green alga, *Microcystis*, in western Lake Erie in late summer and early fall of 1995. Blooms of other species of blue-green algae were common in the 1960s prior to initiation of phosphorus control programs from 1972 to 1980 (Great Lakes Water Quality Board 1985). The 1995 bloom is the only one recently, and its occurrence may be another manifestation of ecosystem changes due to the zebra mussel. The lower abundance of phytoplankton makes more nutrients available, and more light is available due to increased water clarity. Furthermore, Vanderploeg *et al.* (1996) have demonstrated, by use of video studies of zebra mussel feeding, that they reject *Microcystis*, while they continue to filter out other algae.

A major study has been underway in Saginaw Bay, Lake Huron since 1990 to determine overall ecosystem impacts of zebra mussel.

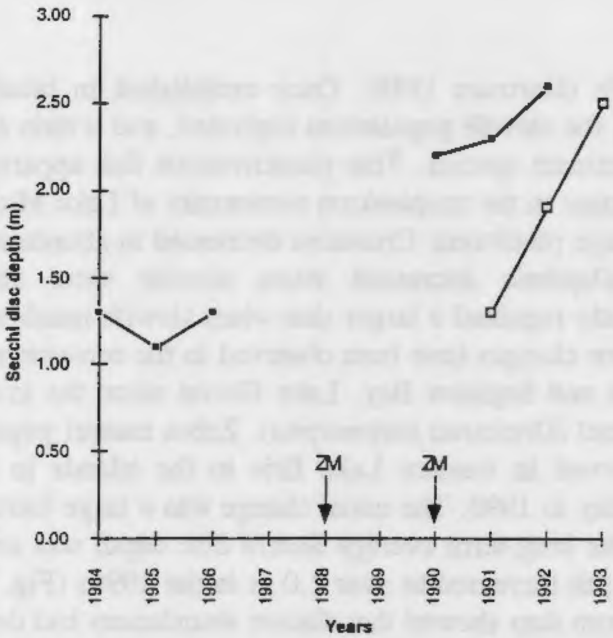

Fig. 3. *Changes in water clarity as measured by secchi disc in western Lake Erie (solid square) and Saginaw Bay (open square).*

The water clarity as measured by Secchi disc has increased 60–100 percent (Fig. 3), depending on the density of the local zebra mussel population (Fahnenstiel *et al.* 1995a). The increase in clarity is consistent with the study made by Fanslow *et al.* (1995) that shows zebra mussels could filter the entire volume of the inner bay on an average of every 0.8 day in 1992 and 5.0 days in 1993.

Chlorophyll declined from 59 to 66 percent in the inner bay (Fahnenstiel *et al.* 1995a). Estimates of phytoplankton productivity decreased by 38 percent (Fahnenstiel *et al.* 1995b). Mesocosm studies showed that while zebra mussel filtration decreased the abundance of phytoplankton, the growth rate of the remaining algae increased (Heath *et al.* 1995). Also, despite the decrease in diatoms and green algal biovolumes of 60 and 40 percent, the biovolume of cyanophytes was unchanged. These differences in biovolumes may be due to the rapid growth of cyanophytes in response to an increased supply of nutrients as well as the rejection of cyanophytes as observed by Vanderploeg *et al.* (1996).

Total suspended solids, particulate organic carbon, particulate phosphorus, and particulate silica all decreased 1991–1993 (Johengen *et al.* 1995). Dissolved nitrate, ammonium, silica, and total dissolved phosphorus increased 1991–1992, but concentrations of the chemicals were closely similar to the 1991 values in 1993. This may reflect the reduced zebra mussel population in 1993 (Nalepa *et al.* 1995). The mean abundance of zebra mussels on hard substrate in the inner bay were 10 130, 33 838 and 3 975 per m^2 in 1991, 1992, and 1993, respectively.

The abundances of all major zooplankton groups either appeared unaffected by zebra mussels or showed significant decreases (Bridgeman *et al.* 1995).

The areal extent of macrophyte distribution increased 13–15 percent as a consequence of the increase in depth of light penetration (Skubinna *et al.* 1995). Major changes also occurred in the benthic algal community. The algal biomass, chlorophyll, and benthic primary productivity all increased (Lowe and Pillsbury 1995). Furthermore, the benthic algal community changed from one dominated by diatoms to a dominance of zygnematales.

All the available data for western Lake Erie and Saginaw Bay show significant changes not only in water quality, but in ecosystem processes (Fig. 4). It is likely that zebra mussels are enhancing the remineralization of nutrients (Gardner *et al.* 1995). Zebra mussels may control ecosystem processes by increasing the rate of nutrient regeneration and, therefore, alter processes which are rate limited and/or concentration limited (Heath *et al.* 1995). Consequently, growth rates of P limited phytoplankton would increase and be controlled by P release by zebra mussels. A phytoplankton community would change from species which have affinity for low concentrations of P to a community dominated by species with rapid growth responding to an increased regeneration of nutrients by zebra mussels (Heath *et al.* 1995).

The increased water clarity suggests a reversal of eutrophication. Nevertheless, examination of the changes documented for Saginaw Bay suggest decreased productivity in the water column, but these are not overall changes in the ecosystem productivity or trophic state, rather they demonstrate a shift in partitioning or allocation of resources and associated productivity (Fahnenstiel *et al.* 1995b). Decreases in phytoplankton productivity are offset by increases in benthic productivity. Zebra mussels have enhanced the benthic/pelagic coupling.

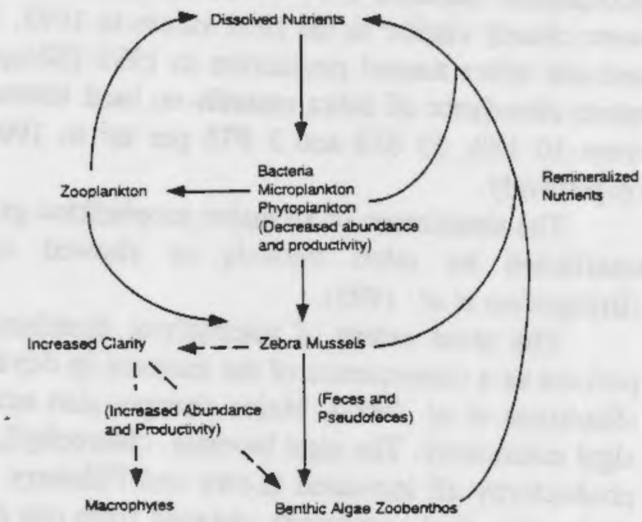

Fig. 4. *Conceptual model of zebra mussel effect on the foodweb and nutrient cycle in the Great Lakes.*

References

Baldwin N.S., Saalfeld, R.W., Roussaud M.A. & Buettner H.J. 1979. Commercial fish production in the Great Lakes 1867–1977. Great Lakes Fish. Comm., Tech. Rep. 3, 187 p.

Bridgeman T.B., Fahnenstiel G.L., Lang G.A. & Nalepa T.F. 1995. Zooplankton grazing during the zebra mussel (Dreissena polymorpha) colonization of Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 567–573.

Fahnenstiel G.L., Lang G.A., Nalepa T.F. & Johengen T.H. 1995a. Effects of zebra mussel (Dreissena polymorpha) colonization on water quality parameters in Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 435–338.

Fahnenstiel G.L., Bridgeman T.B., Lang G.A., McCormick M.J. & Nalepa T.F. 1995b. Phytoplankton productivity in Saginaw Bay, Lake Huron: effects of zebra mussel (Dreissena polymorpha) colonization. J. Great Lakes Res. 21: 465–475.

Fanslow D.L., Nalepa T.F. & Lang G.A. 1995. Filtration rates of the zebra mussel (Dreissena polymorpha) on natural seston from Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 489-500.

Gardner W.S., Cavaletto J.F., Johengen T.H., Johnson J.R., Heath R.T. & Cotner J.B. Jr. 1995. Effects of the zebra mussel, Dreissena polymorpha, on community nitrogen dynamics in Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 529-544.

Great Lakes Water Quality Board, 1985. Report on Great Lakes Water Quality to the International Joint Commission.

Hartman W.L. 1988. Historical changes in the major fish resources of the Great Lakes. In: Evans M.S. (ed.), Toxic contaminants and ecosystem health: a Great Lakes focus. John Wiley and Sons Inc., pp. 103–131.

Heath R.L., Fahnenstiel G.L., Gardner W.S., Cavaletto J.F. and Hwang S.J. 1995. Ecosystem-level effects of zebra mussels (Dreissena polymorpha): an enclosure experiment in Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 501–516.

Holland R.E. 1993. Changes in planktonic diatoms and water transparency in Hatchery Bay, Bass Island area, western Lake Erie since the establishment of the zebra mussel. J. Great Lakes Res. 19: 617–624.

Holland R.E., Johengen T.H. & Beeton A.M. 1995. Trends in nutrient concentrations in Hatchery Bay, western Lake Erie before and after Dreissena polymorpha. Can. J. Fish. and Aquat. Sci. 52: 1202–1209.

Johengen T.H., Nalepa T.F., Fahnenstiel G.L. & Goudy G. 1995. Nutrient changes in Saginaw Bay, Lake Huron, after the establishment of the zebra mussel (Dreissena polymorpha). J. Great Lakes Res. 21: 449–464.

Nalepa T.F., Wojcik J.A., Fanslow D.L. & Lang G.A. 1995. Initial colonization of the zebra mussel (Dreissena polymorpha) in Saginaw Bay, Lake Huron: population recruitment, density and size structure. J. Great Lakes Res. 21: 417–434.

Skubina J.P., Coon T.G. & Batterson T.R. 1995. Increases abundance and depth of submersed macrophytes in response to decreased turbidity in Saginaw Bay, Lake Huron. J. Great Lakes Res. 21: 476–488.

Vanderploeg H.A., Liebig J.R., Nalepa T.F., Johengen T.H. & Strickler J.R. 1996. Zebra mussels may be promoting Microcystis blooms in Saginaw Bay and Lake Erie through selective filtering and nutrient excretion. Sixth International Zebra Mussel and Other Aquatic Nuisance Species Conf., Dearborn, MI. Abstract: 71.

Wells L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. Limnol. Oceanogr. 15: 556–565.

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This volume contains altogether 76 articles and abstracts of presentations delivered at the Second International Lake Ladoga Symposium that was held in Huhmari Congress Centre near Joensuu on 26–30 August 1996. The papers are divided into five sections as follows: Present state and pollution sources of Lake Ladoga (21 papers); Hydrology and physics of Lake Ladoga (11); Ecological studies of Lake Ladoga (19); Studies of other water bodies (16); Socio-economic aspects of aquatic environment problems (9). A list of symposium participants is included.

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