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ZEBRA MUSSELS AND OTHER EXOTIC SPECIES IN THE GREAT LAKES: A PRIMER FOR NON-SPECIALISTS

M.N. Charlton

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Zebra Mussels and Other Exotic Species in The Great Lakes: A primer for non-specialists

By

Murray N. Charlton
National Water Research Institute
Environment Canada
Burlington, Ontario

This report is intended as a quick guide for non-specialists who need a working understanding of the exotic species issue.

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MANAGEMENT PERSPECTIVE

Nature, Great Lakes 2000, Exotic Species, Phosphorus Managament

Since zebra mussels invaded the Great Lakes ecosystem beginning in 1986 there have been an increasing number of inquiries about the mussels and other exotic species. This report is designed to give the non-specialist an elementary knowledge of the exotic species issue. It is not a comprehensive academic treatment of the subject. The author hopes the question and answer format is an aid to accessibility of the information; comments towards future versions are welcome.

Distribute as needed. Update periodically.

This Management Perspective is currently being translated into French.

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Introduction:

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What is an exotic species?

Webster's New World Dictionary has the following definition of the word exotic.

exotic **adj. 1.** foreign; imported; hence, **2.** Having the charm or fascination of the unfamiliar; strangely beautiful, enticing, etc. **n. 1.** A foreign or imported thing. **2.** A plant that is not native.

The word "exotic" is often used to describe something that is charming, unfamiliar, strangely beautiful or enticing. In Biology, however, "exotic" is used as an adjective for foreign or imported species or as a noun for a foreign or imported species. The word "species" can be either singular or plural.

How long have exotics been here and how did they get here?

Exotic species are all around us. From starlings to English sparrows to European beech trees deliberate introductions to North America have occurred for hundreds of years. In the Great Lakes fish community, the common carp was introduced accidentally over 100 years ago. The sea lamprey and alewife arrived from the sea with construction of canals that allowed shipping between rivers connecting to the sea and Lake Ontario and then Lake Erie. Zebra mussels *(Dreissena polymorpha)*, quagga mussels (*Dreissena bugensis*), and the spiny water flea (*Bythotrephes cederostroemi*) are recent arrivals that came from Europe in the ballast water of ocean going ships. These animals come from fresh or brackish water in European harbours that have been cleaned up enough to allow their existence. Zebra Mussels are thought to have arrived in Lake St. Clair around 1986. Since then several other exotics have been found; ballast water is the likely medium of transport.

How many exotic species are in the Great Lakes?

A few years ago the number of known exotics was estimated at 139 plant and animal species. About one third of these were introduced in the last 35 years since the opening of the St. Lawrence Seaway. The number of exotics continues to grow. As recently as November 1998 a new species was confirmed in Lake Erie.

Are all exotics destructive?

Most of the exotics in the Great Lakes have fitted in with relatively benign effects or have been here so long that we can no longer discern their effects. About fourteen species are noted for the problems they cause. Since the introduction of zebra mussels the most feared species are fish: the river ruffe and round nose goby. While their eventual effect will not be known for some time it is feared that they will somehow displace native species of fish.

What is a zebra mussel? What is a quagga mussel.

Zebra Mussels are mollusks most similar to the mussels commonly available in fish shops and restaurants. They are similar to edible mussels in that they attach themselves to a substrate with tough threads known as the byssus. A tuft of these threads is often seen on the commercial mussels. The attachment between the byssal threads and the substrate is very tenacious and has been likened to nature's form of "Crazy Glue". The two half shells of the mussels open upwards like a clam. Unlike clams, the mussels are not buried in sediment but are attached to objects including other mussels. The mussels will live upside down on the bottom of boats or other objects. The zebra mussel has alternating light and dark stripes and is flattened on the bottom where it attaches. There can be a variety of shapes and sizes and coloration hence the species name *polymorpha*. When *Dreissena bugensis* appeared in the Great Lakes they were mischievously named quagga mussel after the extinct zebra like animal that lived in Africa. Quagga mussels tend to have less colour, are flatter, and tend to live in deeper water than zebra mussels. The size of the mussels ranges from microscopic to about 2.5 cm (1 inch) long. They generally live up to two 2 years.

Why are we so concerned about Zebra mussels?

Zebra mussels colonize industrial and municipal water intakes to the extent that flow may be virtually blocked. Extensive cleaning of structures is needed. The main countermeasure now is to pump chlorine out to the site of the intake. As the chlorine mixes with the intake water the mussels are killed. On boats that are not protected with antifouling paint the mussels build up a layer that slows the boat and this reduces fuel economy.

Ecologically, the mussels are covering every bit of hard substrate in lakes and rivers. They filter algae out of the water and deposit their faeces among the dense matrix of their neighbours' shells in the colonies. The algae are at the bottom of the food chain and would otherwise provide food for zooplankton (tiny crustaceans that filter algae) that are, in turn, food for small fish. Thus, there is a concern that immature stages of fish may be starved by the mussels. On the other hand, the mussel colonies are populated by large numbers of other animals that would not, otherwise, be there. Thus, species of fish that specialize in benthic (bottom) feeding may do well. The mussels colonize shells of native clams. The clams usually do not survive and are now rare or non-existent where there are *Dreissena sp.* mussels. Diving ducks now remain in the lower Great Lakes for longer periods of time during their migrations apparently to feed on the zebra mussels. In doing so they are exposed to a new source of contaminated food.

What can we do about Zebra Mussels?

Not much. We are learning to cope with the mussels through various mitigation strategies at water intakes. There is nothing we know of that would eliminate or control the mussels in lakes and still allow the lakes to function as ecosystems. In short, poisoning the mussels is impractical in the Great Lakes and the ecological effects would be undesirable anywhere. It seems that sturgeon and a recent fish invader, the round nosed goby, are eating mussels and that bass are eating the gobies. Thus, the ecosystem is adjusting to the mussels and this is largely not in our control.

What is the lead agency for Zebra Mussels and other exotics?

The federal Department of Fisheries and Oceans is the lead agency for zebra mussels but Environment Canada, Ontario Ministry of Natural Resources and Ontario Ministry of the Environment are also involved.

What might limit the spread of zebra mussels?

Water softness seems to control the distribution in Europe. When the water has low levels of calcium the mussels are at a disadvantage as they attempt to build their shells. In Ontario, this may limit their distribution to areas south of the Canadian Shield. The behaviour of the mussels in North America does not always parallel the experience in Europe, however, hence the species is called polymorpha meaning many shapes or adaptable. Likely, any lake that has clams may support some *Dreissena sp.* mussels.

The mussels are not limited to hard substrates such as rocks as originally thought. Large sand grains are enough to support the initial settlement of the microscopic larvae. Previously colonized areas now export shell fragments of dead mussels. These shell fragments can migrate around the bottom of lakes and eventually become the locus of new colonies. The quagga mussel is less dependent on hard substrate and has colonized the sediments of Lake Erie's east basin at a depth of 62M.

Won't the mussel populations naturally die down?

In Europe, the mussel populations vary by a factor of 10 or more between years. We don't know why there are such large variations. In North America the mussels reach numbers per square metre much higher than in Europe. The success of the mussels does vary here but there does not appear to be any reason now to assume that there will be a large and permanent decrease in the populations.

How can the mussels spread so quickly?

The mussels are hermaphroditic; they simply release eggs and sperm into the water and this relieves them of any complicated breeding behavior. Each individual releases thousands of eggs. The hatchlings are called veliger larvae. The veligers swim in the water and grow for 2-4 weeks before the shell they form becomes too heavy to support. Then they must find a surface to attach to. In the meantime they move with the currents in the river or lake like other plankton. Thus, the pattern of colonization of Lake Erie was from west to east and took about 3 years.

What is a good way to monitor for the presence of mussels?

Prior to a widespread infestation, a population of mussels can be detected in the summer by the presence of the veliger larvae in the water. This requires examination of water samples with a microscope. Obviously, adults would already be in the water system somewhere if veligers are detected so only scant warning of the population build-up is possible. An infestation can easily be detected if a piece of common yellow polyethylene rope is suspended in the water. Periodic examination will reveal tiny mussels attached to the rope.

What about food chain effects of mussels on fish populations?

Scientists are still working on this. Initial fears that reef spawning species such as walleye would do poorly have not been substantiated. So far, the main decrease in lake productivity has coincided with the success of phosphorus loading controls agreed to with the U.S. under the Great Lakes Water Quality Agreement. The degree to which the fish populations may be reduced by lower nutrient levels is not yet apparent and the arrival of the mussels shortly after the nutrient load goals were achieved complicates the picture. Nevertheless, there are good reasons to suspect food chain effects on young fish which may show up as decreased populations later. This topic will be discussed at the "Lake Erie at the Millennium Conference" at University of Windsor in April 1999 and at the annual conference of the International Association for Great Lakes Research in May, 1999.

What can we do about introduced species in the Great Lakes?

Initially, ships were asked to exchange ballast water at sea. The theory was that the salt water would kill the organisms living in fresh or brackish water ballast taken on in European ports. In reality, it is difficult to ensure that all freshwater organisms would be killed due to ballast exchange. Moreover, the practice is apparently unpopular for safety reasons. Other options may include filtration of the ballast, heating the ballast, or poisoning the ballast. These options are yet to be developed. The only sure way to stop the introduction of more exotics via ballast water suggested so far is to stop access of salt water ships to the Great Lakes. Of course this suggestion is unattractive on economic grounds.

What is the link between the zebra mussel and phosphorus control issues?

The Canada- U,S. Great Lakes Water Quality Agreement (GLWQA) signed in 1972 contained provisions to reduce obnoxious algae problems by reductions in the loading of phosphorus. Target phosphorus loads were achieved mainly by construction of sewage plants and the adoption of phosphorus precipitation techniques at the plants around 1986. The target loads are about one half the peak loads of the early 1970s and lake wide phosphorus concentrations have responded in proportion.

Recently, management of the phosphorus loads in the lower Great Lakes has been questioned. The appropriateness of the GLWQA loading targets has been questioned in light of the changing lake ecology brought about by zebra mussels and quagga mussels (*Dreissena sp.*) that invaded the lower lakes beginning in 1986. Fluctuations and declines of some fish species have been noted or perceived by the commercial and sport fishery industries. Declines of some fish species are thought to be caused by excessive grazing pressure of the mussels at the bottom (algae) of the food chain. At the same time, food webs are changing with the emergence of a mussel (*Dreissena sp.*)-goby-bass food chain. Unprecedented low phosphorus values have occurred in the east and central basins of Lake Erie since the *Dreissena sp* invasion. These concentrations were lowest in 1995 and have increased in 1996 and 1997. Although water clarity has changed little offshore in Lake Erie after the mussel invasion (Charlton et al. 1998) there has been a noticeable increase in clarity in shallower nearshore areas (Howell et al. 1996). due to the mussels' filtration (grazing) effects. Chlorophyll (algae) concentrations do not seem to have changed much in the offshore waters of the central and east basins of Lake Erie coincident with the *Dreissena* invasion compared to the decrease that occurred earlier due to nutrient reduction. This means that, although lake productivity is lower than in the early 1970s, the majority of production decrease occurred before mussels arrived. In addition, there may be delayed effects of the achievement of the nutrient load targets that reinforce, or are even more important than, the effects of mussels. The mussels can cause pronounced depletion of algae in nearshore areas (Graham et al. 1996) and this may be where the early life stages of the fish are most susceptible to lack of food caused by excessive grazing by the mussels. At this time, whether or how the mussels affect fish populations is a subject of ongoing research.

Some of the rhetoric about the phosphorus issue has suggested that fish populations are at risk from low phosphorus. When the phosphorus minima occur offshore in the summer in Lake Erie the concentrations of phosphorus are still higher than those in Lake Huron and this reflects the nutrient load and morphometry of Lake Erie. Lake Huron still has a fishery. Thus, there is probably no threat to the survival of fish in Lake Erie from present phosphorus and chlorophyll concentrations alone. The amount and type of fish harvest that is sustainable may, however, be affected.

Some rhetoric on the phosphorus management question has implied that nutrient controls take phosphorus out of the lake. Other rhetoric suggests that historic deforestation decreased the phosphorus supply to the lakes. Both of these assertions are erroneous. Nutrient controls have simply decreased the rate of increase in phosphorus concentrations; nitrogen concentrations have risen as a result because of reduced demand and relatively little removal at sewage plants (Charlton et al. 1998). Forests by nature conserve nutrients. Thus, deforestation and subsequent land use for agriculture has increased nutrient loads to lakes such that a great deal of effort is now expended to reduce nutrient loss from farm lands.

In some situations such as Kootenay lake phosphorus concentrations were thought to be too low as a result of physical modifications to the river/lake ecosystem and phosphorus was added with positive effects. Other disruptions to natural phosphorus supply occur due to fishing of migratory salmon that would otherwise return to their hereditary streams to spawn and die. The annual return of the salmon represented a significant source of nutrients that is now prevented by the extent of fishing of the salmon near the mouths of rivers. Experiments are underway to replace artificially the nutrients now intercepted downstream.

One solution for perceived low fish production, suggested by some fishing interests, is relaxation of phosphorus removal by precipitation reaction during winter months at sewage plants. The historical data indicate that the nutrient loading reduction caused a decrease of around 3ugP l^{-1} in the central and east basins of Lake Erie (Charlton et al. 1998. Therefore, assuming the lake functions as before, a return to nutrient load pollution levels of the 1960s would be needed to increase phosphorus by a similar amount. Much of the phosphorus load reduction, however, resulted from control of raw sewage and partially treated sewage. Thus, only a portion of the difference between pre-and-post phosphorus control loads would be made available by any simple shift in technology such as cessation of phosphorus precipitation at sewage plants. Most of the sewage phosphorus load now under control which might be made available is discharged in the west basin. Increasing west basin loads would have little effect on phosphorus in the central and east basins unless a return to gross pollution year round were allowed.

Concerns with this idea would be the operational practicality at sewage plants, the effects on landowners, drinking water quality, beach quality, and the co-emission of toxic chemicals which may be removed along with phosphorus. In addition, more nutrient loading may have other deleterious effects by stimulating production of blue-green algae which now seem to be favoured in the west basin. Of course, the conditions of tributaries and the effects of more nutrients on shoreline properties already beset by noxious accumulations of *Cladophora sp.* algae (T. Howell, Ont. Min. Environment, personal communication) would have to be taken into account if an attempt were made to fertilize the nearshore areas or even the lake as a whole.

Apparently, fishing in Lake Erie was adequate in the period 1985 to 1990 when offshore chlorophyll was almost as low as in the recent years. Thus, it is doubtful that whole basin nutrient additions from sewage would be sufficient to significantly influence fish production now. One possibility is that the mussels' algal grazing capability which is clearly superior to that of zooplankton would enable them to consume any additional algae stimulated by more phosphorus. The result may be more mussels and not many more fish. A fruitful line of research may be to determine how and whether the mussels may be affecting particularly vulnerable life stages of fish that may inhabit shallow areas.

The success of the mussels varies greatly between the years and the presence of the veliger larvae varies as well and there may be the possibility that mussel populations will decline over time. This, in addition to the recent increase in phosphorus, indicates that more years of experience with the changing species composition and their effect on the lakes are needed to fully understand effects and potential for management. Scientific consensus is that a change in Great Lakes phosphorus management policy is not advisable at this time.

The present sewage loading limits in the Great Lakes are regulated on an effluent concentration basis. Thus, the load of phosphorus can gradually increase due to population growth. Fortunately, more diligent application of present phosphorus removal techniques can be applied in order to maintain or decrease loads from sewage. Amelioration of local eutrophication problems in areas of concern (identified in the GLWQA) would cause a nutrient load reduction to the lakes. Non-point sources are numerically very important now and these will decline if objectives to ameliorate conditions in tributaries and to prevent loss of valuable soil are successful. Non-point phosphorus loads are mainly poorly available to algae because the phosphorus is bound in soils except immediately following rain when fields have just been fertilized. Thus, although the total phosphorus load to the lake may decrease further due to non-point controls, only a small part of that decrease would potentially affect lake productivity. The GLWQA sought to limit productivity of Lake Erie as a way of improving water quality, beach quality and fish habitat while preventing auto fertilization of the lake from sediment phosphorus regeneration. Some decline in lake productivity would be expected but at this time we do not know whether this will be ameliorated or exacerbated by the food chain shift to benthic populations.

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NATIONAL WATER RESEARCH INSTITUTE

INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX

National Water Research Institute
Environment Canada
Canada Centre for Inland Waters
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
Canada L7R 4A6

National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan
Canada S7N 3H5

Institut national de recherche sur les eaux
Environnement Canada
Centre canadien des eaux intérieures
Case postale 5050
867, chemin Lakeshore
Burlington, (Ontario)
Canada L7R 4A6

Centre national de recherche en hydrologie
11, boulevard Innovation
Saskatoon, (Saskatchewan)
Canada S7N 3H5

Environment Canada Environnement Canada

Canada