Fish Culture Technical Bulletin
Best Management Practices

THE POTENTIAL EFFECTS OF ZEBRA MUSSELS AND OTHER INVASIVE SPECIES ON AQUACULTURE AND RELATED ACTIVITIES

Note – unless specifically stated, all information on damage, prevention and treatment applies equally to zebra and quagga mussels.

INTRODUCTION

Zebra mussels (*Dreissena polymorpha*) are an exotic species that entered North America in 1986 (Waller et al. 1996) and were first discovered in the Great Lakes in 1988 (Rice 1995). They are native to the Black Caspian and Aral Seas in the Ukraine and southwestern Russia (Kastner et al. 1997). The danger that they pose is two-fold: 1) they filter large amounts of microscopic food from the environment thus disrupting the food chain and 2) they congregate in great numbers which block intake pipes and clog waterways. More specifically, filter feeding by zebra mussels can increase water clarity, posing a risk to light sensitive species and allowing for greater plant growth along with alterations in the cycling of contaminants. Zebra mussels (along with another invasive species, the Round Goby, *Neogobius melanostomus*) have been linked to botulism that is responsible for killing thousands of birds in Lakes Erie, Ontario and Huron. Humans may feel the impact of the zebra mussels most directly in the form of fouled beaches and injuries from coming into contact with the shells.

Zebra mussels have four principle life stages: the egg, the veliger, the spat and the adult (see Diagram 1 and Photos 1 through 3). The veliger is the free-swimming larval stage that feeds on bacteria and phytoplankton and typically lasts 3-4 weeks. The spat (or post-veliger or settler) is a juvenile which has settled and attached itself to a surface but has not yet developed into a shelled adult (Kastner 1996$_a$). Shelled zebra mussels mature in 1-2 years and can spawn year-round depending on the environmental conditions. A single zebra mussel can produce up to one million eggs per year, depending on the climate (Rice 1995).

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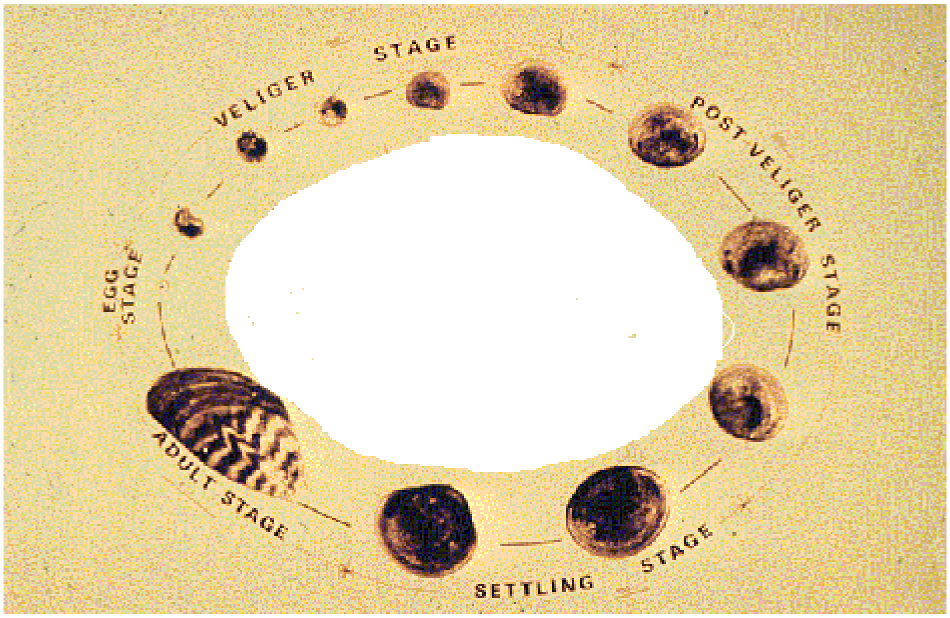

Diagram 1. Basic life cycle of the zebra mussel (modified from Claudi and Mackie 1994).


Photo 1. Veliger.


Photo 2. Post-veliger (spat).


Photo 3. Adults.

All photos are from the GLSGN Exotic Species Library, Ontario Ministry of Natural Resources.

Zebra mussels can grow up to two inches in size and are characteristically D-shaped. Colouration may vary from brown/black with yellow stripes to a solid black or dark brown (Kastner 1996_a) (see Photo 4). They can live for up to three years and filter one litre of water per day (Rice 1995). Zebra mussels are found in clusters, and masses as dense as 100,000 per cubic foot attached to hard substrate have been documented (Kastner 1996_a).

Quagga mussels (*Dreissena bugensis*) are another invasive species closely related to zebra mussels. Visibly they differ in that their shells are often paler and the stripes finer than those of zebra mussels (Sea Grant undated) (see Photo 5). They are also more rounded in shape and don't have a ridge between the side and bottom of the shell (Sea Grant Pennsylvania 2003). Quagga mussels are more common on softer substrate such as aquatic vegetation.

Quagga and zebra mussels are the only freshwater mussels in North America that affix themselves using thread-like fibres to solid objects (Kastner 1996_a). To further verify the identity of a dreissenid mussel, an individual mussel can be placed ventral side down on a flat surface – if it remains upright then it is a zebra mussel – quagga mussels will fall over (Kastner et al. 1997).


Photo 4. An adult zebra mussel. Credit J. Ellen Marsden.


Photo 5. An adult quagga mussel. Credit: J. Ellen Marsden.

Fish culture stations and other types of aquaculture facilities generally provide ideal water conditions in which zebra mussels can thrive. Although survival is possible anywhere between 0 and 33°C, zebra mussels prefer the 13-25°C range. Oxygen levels greater than 2 mg/L are required with 90% saturation being necessary to achieve the highest levels of growth (Rice 1995). Levels of pH between 5.5 and 10 are also needed for survival (Kastner 1996_a).

Quagga mussels may cause even greater problems than zebra mussels in the future. Their habitat requirements are less stringent for colonization and can live on muddy or sandy bottoms (zebra mussels prefer, but do not require, solid substrate). Quaggas appear to have a lower temperature preference (4°C compared to 12°C for zebra mussels) and can occupy greater water column depths (up to 30 m) (Pennsylvania Sea Grant 2003). Quaggas also reproduce at lower temperatures than zebra mussels. Quagga gonadal development has been observed at temperatures under 5°C (Roe and MacIsaac 1997) while the typical reproductive temperature for zebra mussels is 12°C (Mackie et al. 1989). Quagga mussels may therefore pose a greater risk for northern waterbodies than zebra mussels.

DOES YOUR FACILITY ALREADY CONTAIN ZEBRA MUSSELS?

Fish culture facilities may already unknowingly be home to zebra mussels. It is important to periodically examine the facility for the presence of zebra mussels of all life stages. Shelled adults are the only stage easily visible to the naked eye and may be found in pipes, on screens, boat hulls, aerators and any other equipment that has been in contact with contaminated water (Kastner et al. 1997). In more obvious cases, filters and water lines may contain shell pieces from dead mussels and water flow may be restricted (Kastner 1996_a). Veligers can be detected as well using a microscope. Intake pipes should be checked periodically as potential points of entry. However, veligers are tiny and can travel throughout the facility so pipes and tanks should be kept under surveillance. Smooth surfaces (on equipment etc.) that harbour settlers will be grainy to the touch. Veligers are only visible under a microscope and plankton nets must be used to sample the water. Water in tanks, ponds and any surface water source should be sampled. A sample of the material collected in the net must then be placed under a dissecting microscope (further information can be found below under "know your water source"). Note that to inexperienced observers, veligers may be confused with ostracods.

Spats/settlers can be collected using a piece of PVC piping or a plastic mesh pot scrubber (this may also capture veligers). The collection material should be placed approximately six inches below the surface and should be checked for zebra mussels a minimum of once every two weeks (Kastner et al. 1997).

WHAT DAMAGE CAN BE DONE BY ZEBRA MUSSELS?

The largest potential source of damage by zebra mussels within a hatchery is the clogging of water supply pipes. The congestion of filters and pipes can reduce water flow, thus interfering with the quantity of the production water. It has been noted that horizontal pipes tend to have greater levels of settlement than vertical pipes (Claudi and Mackie 1994). Intake points are especially favoured due to the flowing water which continuously brings a supply of food (Anonymous 1998). Zebra mussels will attach to ANY submerged solid surface, although there is a preference for rough surfaces (Claudi and Mackie 1994). Pumps and aerators used in head ponds or rearing ponds can become clogged if zebra mussels colonize and this can lead to equipment malfunction and damage. If sufficient numbers become attached to a particular piece of equipment (i.e., pump or aerator) the mussels could sink it (Rice 1995).

The presence of zebra mussels in a rearing pond could be indirectly deadly for the fish. Large amounts of phytoplankton can be drained from the food chain over a short period of time, depriving the fish of a food source, and clarifying the water and increasing visibility for avian predators (Rice 1995). Zebra mussels can interfere with cage culture by settling on the nets and obstructing the flow of water, subsequently decreasing oxygen availability (Rice 1995). Zebra mussels may also pose a disease risk to both cultured and wild fish. In Europe and Russia, the mussels are known to harbour parasitic and digenetic trematodes, respectively. *Phyllodistomum folium* and *Bucephalus polymorphus* occur in Europe and have been the cause of several fish kills. To date, these trematodes have not been found in North American zebra mussels (Kastner and Guyton 1997).

The presence of zebra mussels, or even a perceived presence, could negatively affect private businesses. The public may be reluctant to purchase food fish or bait fish from a supplier whose product may have come into contact with zebra mussels (Kastner et al. 1997).

HOW TO PREVENT THE ENTRY OF ZEBRA MUSSELS INTO THE FISH CULTURE FACILITY

Know your points of entry

Zebra mussels can enter a facility through many pathways:

- Intake pipes placed in water that contains zebra mussels;
- Contaminated equipment (i.e. aerators, pumps, boats, nets, buckets, transport tanks etc.);
- Fish from infected hatcheries;
- Holding water from wild collections;
- Broodstock from contaminated waters; and
- Aquatic plants with attached spat.

Know your water source

Nearly all Ontario surface waters are susceptible to colonization by zebra mussels. Creeks, rivers and lakes should be avoided as water sources if possible. Groundwater/well water is preferable in that it is free of zebra mussels. Inspect your source water. Plankton nets of a minimum mesh size of 76 µm can be used to test a questionable source waterbody. Maximum densities of veligers occur in water 3-7 m in depth along the perimeter of the lake. They congregate in large clumps and experience a diurnal migration so it is important to take numerous samples. When searching for adults, depths of 2-4 m are typically occupied (Deacon and Marsden 1993). If there is knowledge of or suspected contamination of a source waterbody by zebra mussels then filters may be used to exclude all life stages of zebra mussels. A filter of a minimum of 40 µm can be used to remove the larval stage and larger (Claudi and Mackie 1994). However using mechanical filtration may reduce the water flow sufficiently that it affects production (Rice 1995). A sand filter or buried intake pipe may be useful in that it should filter the zebra mussels without interfering with water flow (Rice 1995, Terlizzi 1995).

Pre-treat your in-water structures

Some structures (or equipment) may be treated with anti-fouling agents. Once applied, these agents act as a repellent to settling organisms. In Canada, use of coatings which contain the biocide TBTO (tributyl tin oxide) is prohibited. As an alternative, there are silicone-based paints which prevent and/or decrease zebra mussel incidence of attachment. Unfortunately, numerous layers must be applied at a total cost of \$80-100/m^2 and the protection lasts for only 4-5 years (Claudi and Mackie 1994).

Disinfect all equipment

All equipment that is used in water outside of the fish culture station must be thoroughly cleaned and disinfected prior to it entering the station, or coming into contact with station products (fish, eggs, water and other equipment). Prior to disinfection, manually remove visible debris such as vegetation.

Disinfection techniques include:

- Constant contact of equipment with water heated to 60°C for 3-4 minutes (Kastner and Guyton 1997).
- Drying large items for at least five days (Skinner and Ball 2004). Note that the drying period can vary significantly and depends on the climate. Zebra mussels can live for more than 10 days out of water when the air is moist and the temperature is less than 15°C (Claudi and Mackie 1994, Kastner and Guyton 1997). Rainfall and morning dew can extend the lives of attached zebra mussels.
- Cleaning equipment using a pressure washer that exerts a minimum force of 250 psi (Kastner et al. 1997, Skinner and Ball 2004).
- Freezing equipment by exposing it to temperatures below 0°C for a minimum of two days (Kastner and Guyton 1997).
- Soaking nets and other submersible equipment in a variety of solutions (Skinner and Ball 2004)
    - Salt water – approximately 33 g of salt to 1 L of water
    - Bleach –approximately 4 ml of bleach to 1 L of water

<u>Fish from infected waters</u>

Waterbodies that are to be used as a source for broodstock and/or gametes should always be investigated in advance for zebra mussel populations. For reference, the following website provides a map showing the known distribution of zebra mussels in Ontario: http://www.invadingspecies.com/index.cfm?DocID=23&Type=Zebra_Mussel. Contact the Invading Species Hotline, managed by the Ontario Federation of Anglers and Hunters (OFAH), in partnership with the Ontario Ministry of Natural Resources, at 1-800-563-7711 for further details. When purchasing fish from another fish culture station, stipulate that proper transport water disinfection procedures are followed and/or ensure that the facility and product is zebra mussel-free.

Spawn collections

Wild spawn collections are potential entry points for zebra mussels into the fish hatchery. It is important to abide by the following guidelines in order to minimize the risk of zebra mussel contamination:

- Always bring water from the hatchery (or another source known to be zebra mussel-free) when undertaking a spawn collection if feasible. This ensures that all the water the eggs and milt come into contact with is free of zebra mussels and therefore eliminates a possible point of entry. If it is not possible to bring water then the transportation water should be treated using a salt solution as recommended below under “Fish transfers.”
- The hatchery water must be used to water harden the eggs. This practice protects against any unknown contaminants (whether they be chemical or biological) in the source waterbody.
- All equipment (waders, measure boards, nets etc.) that is to be employed must be disinfected (as is outlined above under “Disinfect all equipment”) prior to and after use. It is important to recall that eggs and veligers are not visible to the naked eye and assumptions as to the zebra mussel (or exotic species) status of the waterbody should not be made.

Fish transfers

Similar to the dumping of bait buckets, fish transfers from one waterbody to another can spread zebra mussels. The following guidelines should be adhered to when: 1) transferring fish from one waterbody to another, 2) transferring fish from one fish culture station to another, 3) transferring fish from a fish culture station to a waterbody for stocking or 4) transferring fish from a waterbody to a fish culture station.

- Fish transfers should be limited to waterbodies and fish culture stations of known zebra mussel and/or exotic species status, when possible. This will limit the spread of zebra mussels.
- In a fish culture station setting, ensure that all fish are dry-loaded (dewatered) if possible (Festa 1994).

- Transport the fish in filtered water or groundwater. If the statuses of the waterbodies involved are questionable then this is especially important. It is easy for veligers to be attached to plant matter or other small debris in the water.
- A salt solution should be used to treat the transport water. This still applies if using groundwater or filtered water when transporting fish from a waterbody of unknown zebra mussel status. Softener salt contains 99% potassium chloride (KCl) and 0.7% sodium chloride (NaCl) and can be used as the source for KCl in any of the following recipes (Culver 1998 *In* Hilt 2000).

  1) For walleye, saugeye, fathead minnows, rainbow trout, brown trout and muskellunge (Edwards et al. 2000, Edwards et al. 2002):
  - A one hour pre-treatment of 750 ppm KCl followed by a 25 ppm 2-hour formalin treatment is recommended.
  - Note that the use of NaCl to relieve osmotic stress to the fish is NOT recommended when using this formulation. Trials demonstrated that the NaCl reduced the effectiveness of the formalin and KCl treatment and that KCl sufficiently reduced stress on its own.

  2) For adult fish and trout and musky greater than 150 mm in length (Culver 1998 *In* Hilt 2000):
  - Treat the fish with a concentration of 100 mg of 40% formalin per litre for a minimum of two hours.

  3) For fingerlings – walleye, saugeye, largemouth bass and channel catfish (Culver 1998 *In* Hilt 2000):
  - Initially treat the fish with a 750 mg/l solution of KCl and then follow with a treatment with a concentration of 20 mg of 40% formalin per litre for a minimum of two hours.

<u>There are only two situations where treatment of transport water would be unnecessary: 1) if a fish culture station that is supplied with groundwater or filtered water was to transport fish to another station or waterbody for stocking, or 2) if the recipient waterbody was known to be already highly contaminated with zebra mussels.</u>

HOW TO TREAT FOR ZEBRA MUSSELS

Non-chemical methods

Zebra mussels can be eliminated from rearing ponds following fish harvest. The ponds should be drained completely and left to dry for a minimum of two weeks – ensure that the water drained from ponds does not drain into a nearby waterbody. The water should drain onto land where it will be absorbed by the earth and/or disappear due to evaporation. Any zebra mussels will die due to desiccation. It is preferable if this is done in either very hot or very cold weather. To further ensure all zebra mussels are killed hydrated lime/calcium hydroxide (CaOH) can be added at a rate of 1,120-2,240 kg per ha) (Kastner et al. 1997). Equipment can be treated using heat or desiccation as mentioned in "How to prevent a zebra mussel invasion."

Although it may appear ideal in a pond rearing situation, biological control is not recommended. Freshwater drum (sheephead), common carp, blue catfish and redear sunfish are all documented consumers of zebra mussels. However, their consumption levels are inadequate to control them. In Europe during the 1960s black carp were studied as a solution to the zebra mussel problem, but were found to be ineffective (Rice 1995).

Chemical methods

As of yet, no chemical has been identified that can kill all stages of zebra mussels without harming fish.

Certain common aquaculture facility chemicals can be used to clean equipment and tanks. Benzalkonium chloride was determined to be successful, while calcium hypochlorite and iodine were found to be ineffective (Waller et al. 1996, Kastner et al. 1997). Roccal (the commercial name for benzalkonium chloride) kills veligers and adults when used at 100 ppm for 3 hours or 250 ppm for 15 minutes. For ponds, rotenone at 1-5 ppm for 24 hours or chelated copper at 2 ppm for 48 hours can be used (Waller et al. 1996). All three of these substances are harmful to fish and can only be used after the fish are harvested from the tanks and ponds. If a fish culture station is found to contain zebra mussels then all fish at the facility should be stocked in waters known to contain zebra mussels and the entire station disinfected (removal of all adult zebra mussels followed by chemical application). Be sure to follow all instructions on the product label. Before using any pesticide contact your local Ministry of the Environment office to determine what, if any, permits are required in order to use it. Municipal bylaws and regulations may also apply.

Few studies have been undertaken to look at treating for zebra mussels in the presence of fish. As of yet, a complete facility-wide chemical treatment, with fish in the system, has not been documented. See the previous section "Fish transfers" for chemical treatment of fish and water during transportation.

WHAT OTHER INVASIVE SPECIES CAN POTENTIALLY CAUSE PROBLEMS?

The spiny water flea (*Bythotrephes longimanus*) and the fishhook water flea (*Cercopagis pengoi*) are tiny exotic crustaceans. Eurasian water milfoil (*Myriophyllum spicatum*) is one of many invasive plants. All three of these species have the capability to negatively impact rearing ponds and, in the case of the water milfoil and other aquatic plants, intensive rearing facilities as well. Eurasian water milfoil outcompetes the native Northern watermilfoil and can survive under a wide range of conditions (depths of 0.5-10 m, still or flowing or clear or turbid water and pH from 5.4-11). This prolific plant reproduces by runners and pieces of stem and creates substantial masses (OFAH 2004). These large masses can clog intake pipes and affect the flow of water into a facility. In ponds, the degree of sunlight infiltration can be reduced and water may become stagnant (OFAH 2004). Additional information on aquatic invasive species and where they have been found is available through the OFAH/MNR Invading Species Hotline at 1-800-563-7711 or online at www.invadingspecies.com.

STOP THE SPREAD – FINAL RECOMMENDATIONS
(from Festa 1994)

- Use only well water, spring water or filtered water for transporting fish.
- Ensure that all fish that are transported for stocking are dry-loaded (de-watered).
- Do not stock fish from a zebra mussel-infested fish culture station into waters that do not have zebra mussels in them.
- Do not transfer fish from a zebra mussel contaminated fish culture station to one that does not have zebra mussels.

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