RAPID RESPONSE PLAN FOR THE ZEBRA MUSSEL (*Dreissena polymorpha*) IN MASSACHUSETTS

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*cover photo taken from the Nonindigenous Aquatic Species website, http://nas.er.usgs.gov

Species Taxonomy and Identification

The zebra mussel, *Dreissena polymorpha*, is a freshwater bivalve mollusk. Zebra mussels look like small clams with a yellowish to brownish shell shaped like the letter "D". The shell of the zebra mussel normally contains both dark and light-colored stripes, giving the mollusk its name (Figure 1), although some zebra mussels shells may be a solid brownish color. Adult zebra mussels can reach a length of two inches, but typically zebra mussels are one inch or less. Unlike most freshwater mussels, the zebra mussel grows in clusters containing numerous individuals. Zebra mussels are the only freshwater mollusk that can attach to solid objects, including rocks, logs, docks, boats, and various water intake pipes and instruments.

Figure 1 - A photograph of zebra mussels attached to a substrate. This photo is taken from the Michigan Department of Environmental Quality website at www.michigan.gov/deq.

Species Origin and Geography

Zebra mussels are native to the drainage basins of the Black, Caspian, and Aral Seas of Eastern Europe. By the 1830's the zebra mussel had expanded through shipping canals to the majority of Europe. Within the United States, zebra mussels range throughout the Great Lakes, the Mississippi river and its major tributaries, recently in the Chesapeake Bay watershed, and in multiple states from Minnesota to Vermont. The mode of introduction to North America is believed to be cargo ships originating in Europeans ports. Transport across the Atlantic Ocean occurred in the ballast water of the cargo ships that was discharged into Great Lakes Ports. The first discovery of zebra mussels in

North America occurred in Lake St. Clair, Michigan in 1988. By 1991, zebra mussels were confirmed in all five of the Great Lakes, the Finger Lakes area of New York, and in the Mississippi River basin (Figure 2).

Zebra mussels have a high probability for spread. Juvenile and adult mussels are transported by waterfowl and aquatic organisms that serve as suitable attachment hosts (i.e., turtles and crayfish). Eggs and swimming larvae (veligers) can be transported by water flow or in bait buckets, live wells, engine cooling water, scuba diving equipment, and by any transfer of water from an infested waterbody. Natural predators of the zebra mussel are few but include drum, yellow perch, sturgeon, crayfish and various diving ducks (Marsden 1992).

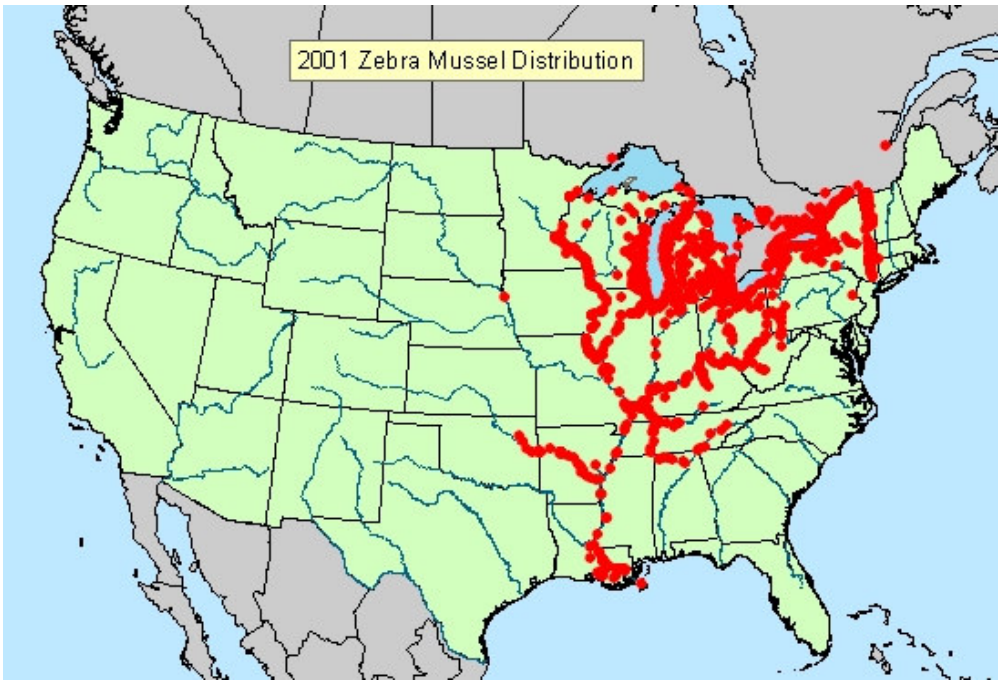

Figure 2 – A map indicating locations where zebra mussels are confirmed. This map is taken from the Nonindigenous Aquatic Species website.

Species Ecology

Zebra mussels are usually found in freshwater lakes, ponds, embayments, and rivers. Zebra mussels typically live 3 to 5 years, but some specimens have lived as long as 15 years (Ludyanskiy et al. 1993). Ludyanskiy et al. (1993) reported that zebra mussels prefer water with salinity below 4 parts per thousand, summer water temperatures between 17-23°C, pH levels between 7.4 and 9.0, dissolved oxygen from 8-10 ppm, turbidity levels of 40-200 NTU, and a calcium concentration from 20-125 ppm. They can survive a range of environmental conditions, although pH and calcium concentration appear to limit the reproductive capacity of a population (Ludyanskiy et al. 1993). Zebra mussels are known to adapt to aquatic ecosystems with chemical parameters outside of the ideal range, and this may allow the mussels to spread to brackish estuaries or sub-tropical regions.

Zebra mussels are filter feeders, and each individual can filter between 1 and 2 liters of water per day (O'Neill and MacNeill 1991). The mussels filter water for feeding and respiration (Karatayev et al. 2002). During filtration, food particles are consumed while other particles are discarded as pseudofeces, and are not resuspended in the water column. Their ability to filter large amounts of water increases clarity and increases the volume of the lake available for photosynthesis. Despite possibly elevated photosynthesis, zebra mussels tend to shift the flow of energy in the aquatic system to benthic pathways.

Zebra mussels reach sexual maturity after one or two years and exhibit external fertilization (Ludyanskiy et al. 1993). Optimal conditions for spawning occur when the water warms above 12°C. Female zebra mussels are very fecund and may produce over 30,000 eggs per reproductive cycle, translating to more than one million eggs per spawning season (Moser 2002). Larvae are planktonic and eventual settle and attach to the bottom (Moser 2002). Zebra mussels are not selective when they colonize, and will settle on any hard substrate including pilings, rocks, buoys, pipes, piers, boats, aquatic plants, and even the shells of other mollusks (Claudi and Mackie 1994). Younger zebra mussels will grow on top of older zebra mussels resulting in giant colonies called druses (Ram et al. 1996).

Detection of Invasion

Zebra mussel discoveries may be made by state agencies performing routine sampling, recreational scuba divers, and water utilities performing routine maintenance or addressing a fouling issue. Swimmers often find infestations unpleasantly, as the shells are sharp and can easily cut bare skin. When a zebra mussel is collected from or reported in a waterbody, a survey should be conducted to quantify the extent of the invasion.

There are multiple methods for conducting a survey depending on the objective of the survey. To quantify the extent of a zebra mussel invasion, it is important to be as thorough as time, money and manpower allow. The following steps should be considered when conducting a survey for zebra mussels:

1. Acquire a suitable map of the waterbody, preferably with water depth contours.
2. Use the taxonomic information supplied here, or supplementary information from taxonomic guides, to identify zebra mussels.
3. Concentrate the survey in areas with suitable hard substrates for attachment.
4. If zebra mussels are collected, mark the position on a GPS for future reference, and to help pin-point key areas in the waterbody.
5. The use of repeatable transects is advised, as the zebra mussels are sessile and can be relocated with proper information.
6. The spacing of transects will be a function of the distribution of suitable substrates; the depth to which a survey is conducted would be to the depth at which soft sediments are exclusively dominant. It may be advantageous to use an underwater viewing tube or videocamera

(Aqua-Vu or equivalent) to scan a greater area more rapidly, but snorkeling should be sufficient as a detection method.

Species Confirmation

Unless the invasion is discovered by individuals trained in mussel taxonomy, samples or digital photographs should be sent to the appropriate authority to confirm the identification. In Massachusetts, the Department of Conservation (DCR) should be the first point of contact. The DCR can be reached at 617-626-1411 or 617-626-1395. For identification of zebra mussels, the photos or specimens should be sent to the DCR or to the expert designated by the DCR for confirmation.

Key steps in confirming an invasion include:

1. Collect a specimen of the suspected zebra mussel and place the specimen on ice.
2. Contact the DCR representative at 617-626-1411 or 617-626-1395 and inform him/her that a suspected invasion of zebra mussels has been detected in the waterbody. The DCR contact will instruct the caller where to send the sample for confirmation.
3. The sample should be sent to the DCR representative for confirmation, or to an expert as designated by the DCR contact. Note in writing that the enclosed specimen is believed to be a zebra mussel and include the name of the waterbody, the approximate location where the specimen was collected, the date and time of collection, and the name, address, phone number and email for the collector or sender.
4. The DCR will confirm the identification or provide an alternative identification either directly or indirectly through a recognized taxonomist, and will be responsible for notifying all appropriate agencies, municipalities and citizen groups either potentially affected or responsible for the follow-up actions.

Quantifying the Extent of Invasion

During the identification process a field crew or multiple field crews should be mobilized to quantify the extent of the zebra mussel invasion. The first step in the quantification process is to determine if the species is isolated within a waterbody. If the body of water contains avenues for the species to move to other waterbodies, these avenues must be identified. If the organism is not isolated, it must be determined how far it has spread from the probable introduction site. To determine if the organism is isolated or how far it has spread, the most rapid and effective assessment techniques include underwater video or snorkel/scuba surveys. The main goal of these surveys is to document the presence and extent of the zebra mussel infestation, and it is important to cover the maximum amount of area possible. The most important aspect of these surveys is to determine if the population of zebra mussels in the waterbody is well established or if the introduction is relatively new and only a few small colonies are present. Through these surveys, agencies will also be able to identify suitable substrate for zebra mussel recruitment in the waterbody being surveyed and can use this information when considering possible management techniques, or areas for future monitoring.

Species Threat Summary

Zebra mussels have caused major environmental changes due to their physical community structure and their filtering capabilities. Their excellent filtering capabilities reduce the amount of phytoplankton and suspended particulates in the water column, resulting in increased water clarity. Increased clarity allows for increased productivity of submerged aquatic vegetation. Zebra mussels can out-compete native filter feeders and may reduce the abundance of native species. Zebra mussels can create large reef-like colonies, altering the physical habitat as well as biological energy flow.

Zebra mussels may disrupt the food chain in a waterbody through direct competition with zooplankton for the available phytoplankton (Karatayev et al. 2002). The encrusting ability of zebra mussels may eliminate or reduce spawning and nursery habitats of demersal fish species. Changes in the trophic structure of aquatic environments may lead to increased numbers of some types of fishes and losses of other types of fishes, impacting the local commercial and recreational fisheries (O'Neill and MacNeill 1991).

Large colonies or infestations of zebra mussels can be responsible for shifts in the taxonomic assemblages of the benthic community. Sedimentation from feces and pseudofeces production can alter the substrate and associated energy availability. The increased sedimentation and reduced phytoplankton tend to increase the presence of deposition feeders (Karatayev et al. 2002). However, in most cases where these shifts have been detected, zebra mussels are still the dominant benthic invertebrate.

The economic impacts of zebra mussels can be extreme, due to their biofouling characteristics (Moser 2002). This biofouling is usually experienced by industrial and municipal entities using intake pipes and screens for water withdrawal. In fact, public utility and industrial facilities have been shut down because of zebra mussel fouling. Dead zebra mussels litter shorelines creating an ever present aroma of decaying flesh, resulting in decreased tourism in some areas of the Great Lakes (Ludyanskiy et al. 1993).

Communication and Education

Preventing and detecting the invasion of zebra mussels in uncolonized waters starts with education of the public, especially boaters and fishermen. For zebra mussels, the first line of defense is often the angler or boater who may observe or potentially transport the invasive mussel. Education of anglers and the public could be undertaken with a short, concise and easily understood pamphlet or information card. These cards and pamphlets could be made available to the public, and handed out to fishermen and boaters each time a fishing license is sold or a boat is registered. This educational material would notify anglers and boaters of the potential for zebra mussels to invade local waters and give the anglers and boaters the capability to identify zebra mussels should any be observed. Included on the pamphlet should be phone numbers and contact information for the agencies involved with non-indigenous species management. It is also important to make people

understand the role of the larval stage (veligers), although recognizing these may be beyond the ability of many laypersons.

When an invasion is identified and confirmed it is critical to notify the public and all appropriate stakeholders through the appropriate outlets (i.e., television and radio news, newspapers, bait and tackle shops, boat ramps, town meetings, lake association meetings, etc.) and suggest appropriate actions should a specimen be encountered. Groups who should be informed about the infestation include any active waterbody association, property owners, boaters, anglers, swimmers and any other group of individuals that come in contact with the waterbody.

It is desirable to post access points with warning signs even before an invasion, displaying a picture or drawing of a zebra mussels and asking the waterbody users to be on the lookout for this invasive mussel. A local contact (name and phone number) for notification should be given, typically either a representative of a state agency or the town's Conservation Commission, or both. Users should be advised to collect the specimen and keep it for identification. It should be stressed that users should not return these mussels to the waterbody from which it was collected or any other waterbody. After an invasion has been discovered, access points should be posted with a warning to users. Again, a picture or drawing of a zebra mussel should be provided. Educating the public is very important, especially since people often move and transport water between waterbodies for the purpose of transporting bait or inadvertently with boats or other recreational equipment.

Responsibility for control of zebra mussels does not rest with any one entity under the laws of the Commonwealth of Massachusetts. Approval for control actions may involve the Massachusetts DEP, Division of Fisheries and Wildlife and/or the Natural Heritage and Endangered Species Program, all agencies of the Commonwealth, depending upon the resources in the waterbody (particularly if protected species are known from the waterbody). Other agencies and approval programs may apply, depending upon the features of the waterbody (naturally large enough to be a statutory Great Pond), the location of the waterbody (e.g., in an Area of Critical Environmental Concern), or the uses of the waterbody (e.g., as a water supply). However, none of these agencies is charged with controlling invasive species, and there is no legislation in Massachusetts that mandates control of zebra mussels. The DCR has taken the lead in Massachusetts with regard to encouraging control of invasive species, and supports control efforts as its budget allows. However, outside of the state parks and reservations, control is largely a function of local desire to protect and maintain the resource, and possibly action by the DFW.

For waterbodies within DCR parks, the following notification procedures are to be followed when a new infestation by zebra mussels has been confirmed:

1. The DCR contact responsible for confirming the zebra mussel invasion will notify the DCR Regional Director, Park Supervisor and any regional DCR contact charged with managing water resources. A single letter copied to each party is preferred. The letter should briefly state the problem and outline immediate control steps that are needed, indicating an expected date for a follow up visit by Lakes and Ponds Program staff to begin concerted control measures (see posting procedures below).

2. The DCR contact responsible for zebra mussel introduction confirmation will also notify the DEP, the DFW and the NHESP in writing; a copy of the letter sent to DCR parties is sufficient. If a contact for an associated citizens' lake or watershed organization is known, notification should be given to that group as well.
3. The Regional Director or a designated park contact for local affairs will notify the town(s) in which the park and waterbody are situated. The appropriate parties within the town(s) to be notified may vary by town, but should include the Conservation Commission and either the Selectmen, Town Manager or Mayor, depending upon local government structure.

For waterbodies within DCR parks, the following posting procedures are to be followed when a new introduction of zebra mussels has been confirmed:

1. All access points to the waterbody (e.g., boat launches, swimming areas, fishing piers or obvious shoreline fishing points) shall be posted with a photograph or drawing of a zebra mussel and a written notice that this invasive mussel has been found in the waterbody.
2. Suggested language is as follows: Warning. Zebra Mussels (*Dreissena polymorpha*) have been found in this waterbody. This invasive mussel represents a threat to this waterbody and its users. Caution should be exercised to avoid the spread of this mussel. If collected, do not return this fish to the waterbody, and do not transport water from this waterbody to other waterbodies. If areas containing these mussels are identified please contact the DCR.
3. Include a contact name and phone number on all postings.

Quarantine Options

Identification and assessment of expansion routes needs to be undertaken immediately after identification of an introduction. These expansion routes must be accounted for, and methods to prevent or slow expansion need to be undertaken to reduce the spread of the organism. Sequestering curtains or screens can be used to restrict access to unimpacted connected waterbodies. If the infestation occurs in a lake or pond with outlets, the outlets should be screened to minimize the export or migration of zebra mussels to downstream areas. This may be problematic where leaves or other debris are abundant enough to clog such screens, necessitating frequent cleaning. Rotating screens or other automated outflow restrictors are effective but expensive.

In large water bodies with multiple outlets, or in streams and rivers, eradication or stopping the spread of the species may be extremely difficult. There are no practical management or quarantine options for controlling a zebra mussel infestation of a stream, river or large lake or reservoir. When an introduction is detected in one of these waterbodies, managers normally focus on slowing the expansion of the species.

Land ownership and access may hinder or slow the response process. When an introduction is identified, the responding agencies must ensure that proper permissions are granted and obtained so the management plan can be implemented as quickly as possible.

There may be some logic in preventing human access to the infested lake, if there is reason to believe that people will knowingly or unknowingly transport mussels elsewhere, but this is rarely necessary with an appropriate education program.

Control of Infestations

Unfortunately, there are few viable techniques for eradicating zebra mussel populations once a waterbody has become infested. The potential control methods for a zebra mussel infestation vary with each specific infestation site; important features include the uses of the waterbody, extent of infestation, size of the waterbody, and linkage to other sites, infested or unaffected.

1. **Drawdown and exposure** - If the infestation is within an impoundment with water level control capability, drawdown may be a viable control technique. Removing all water from a lake or pond and allowing it to dry may eliminate the zebra mussel infestation; however, this technique involves many technical and biological issues. A drawdown of the lake or pond could result in the eradication of many desirable plant and fish species. An effort could be made to capture and relocate desirable species, but this would be an expensive and lengthy undertaking. Impoundments that are spring fed may be difficult to keep dry and the mussels may survive. The water would have to be filtered or otherwise treated to ensure no small eggs or larvae escape. Alternatively, it may be possible to hold the water in a separate basin or to dispose of the water in a way that limits risk of zebra mussel transfer (e.g., ground water infiltration). All of these approaches are likely to be time consuming and expensive, if even practical.

2. **Physical removal** - Physical removal of the mussels using manual scraping and water jets can be used on a small scale with success, but are not likely to be successful for large infestations. If the infestation is believed to be limited to a few individuals or even a few patches of mussels, physical removal may be successful in removing the target organisms. Even with a few individuals, however, it may be difficult to determine if the eradication was 100% successful. One advantage of physical removal is minimal impact on native and desirable species, as these methodologies are localized and can be somewhat selective.

3. **Suffocation** - As zebra mussels need oxygen to survive, one control technique is to reduce the oxygen level below the lethal limit of zebra mussels. However, this will almost certainly have a major impact on other aquatic organisms and is not usually recommended for use outside of industrial facilities.

4. **Thermal treatment** - hot water can kill zebra mussels, although many other aquatic organisms can also be harmed as well. Industrial and public utilities are experimenting with thermal controls for zebra mussels, and on a localized basis this approach may have merit, but it is not a recommended large scale technique for whole lake application.

5. **Biological control** - Augmenting or introducing natural predators and species specific diseases or parasites may be considered, but is not likely to result in the eradication of the infestation. The change in ecosystem dynamics due to introductions of new organisms or the augmentation of present organisms may be detrimental to the overall health of the ecosystem in some cases, so care must be taken with this approach. An exception may be certain fish species, like freshwater drum, which prey upon zebra mussels effectively. As with most biological predator-prey interactions, cycles of abundance are typically set up and eradication is unlikely, but some measure of control can be achieved.

6. **Chemical control** - Industries and public utilities that experience problems due to zebra mussel biofouling may use chemicals to clear the fouling. Chlorine and various pesticides are effective and can be used with limited risk inside those facilities. However, the potential negative effects of chlorine and other chemicals on the aquatic environment may be great if applied in open water. There are no known chemical controls suitable for use against zebra mussels in an open environment. Experimentation with various paints and other applied coatings has shown some promise, but these will not combat existing infestations. If the target area is small and water exchange can be controlled, it may be possible to apply some of the harsher chemicals with limited impacts to non-target populations in the lake, but great care must be taken and this approach has generally not been applied. The Army Corps of Engineers has published a "Zebra Mussel Chemical Control Guide" that can be accessed at http://el.erdc.usace.army.mil/zebra/pdf/trel00-1.pdf. This guide includes information about the various chemical treatments used to combat zebra mussel fouling.

Other control techniques that are currently being used or experimented with by industry and utilities are radiation, mechanical filtration, removable substrates and complete re-design of systems in critical areas. None of these appears particularly applicable for overall lake use.

The aforementioned control techniques may be practical on a small scale, but are likely to be very expensive and less effective on a larger scale. The importance of early detection and rapid response to a new infestation cannot be overemphasized. The expense of larger undertakings alone may limit the ability of public agencies to combat an infestation, and the permitting complications of larger scale efforts may add an additional barrier to success. In many cases, eradicating an introduced population may not be practical, and instead the control and management of the infestation is set as the target goal. In these cases, it becomes a management issue and every effort should be made to control or slow the movements of these mussels to other waterbodies. Each infestation must be handled separately, and the characteristics of each waterbody will dictate which management tools are appropriate

Prevention of Re-Infestation

Once an invasion has been repulsed through any of the above methods, it should be apparent that the waterbody is susceptible to zebra mussels. Complete eradication may not be possible, but where eradication is successful it is important to take steps to prevent re-infestation. Educating the

public is the most important step to combating a re-infestation. Key steps to educating the public may include:

- Education through the lake association or town for all users about the threat of zebra mussels, how to identify them, and who to contact if one is found. See the Communication and Education section in this document for relevant information to be provided.
- Posting of all access points with signs warning of the threat, showing how to identify zebra mussels, and urging fishermen, boaters, and water users to report discoveries of these mussels to the appropriate agency.

Summary

1. The zebra mussel (*Dreissena polymorpha*) is a non-native mussel identified by dark and light colored stripes on its D-shaped shell, which is typically <1 inch long.
2. Zebra mussels are native to Europe, and were introduced to North American and the United States through ballast water releases from shipping vessels.
3. Female zebra mussels are very fecund, and a single female may produce over one million eggs per reproductive season.
4. Expansion of the zebra mussel range has been a function of natural water flow, wildlife (especially bird) activity, and a variety of human pursuits, including boating, fishing and the bait industry.
5. Larval zebra mussels (veligers) may be difficult to detect, but adult zebra mussels tend to grow in clumps on a wide variety of hard substrates and are easily visible with snorkel gear, underwater viewers, or underwater video systems. As the adults are sessile, standard transect methods, as applied for aquatic plant mapping, can be used to search for and quantify the extent of an invasion.
6. Small infested areas could be quarantined and blocked off using curtains. This will impede the movement of zebra mussels until one or more of the applicable control techniques can be applied.
7. Where the infestation is more extensive, it is important to take steps to minimize the transport of zebra mussels out of the lake to other aquatic systems. This may involve screening of outlets, curtaining of interbasin channels, or even preventing human use of the waterbody.
8. Eradication of the zebra mussel may be impractical for large lakes and reservoirs, as well as moving water of streams and rivers. Aside from limitations on technical feasibility, financial and permitting issues are likely to hinder large eradication efforts. It is therefore essential that infestations be detected quickly and that a response be rapid.
9. Management options include physical removal, lake drawdown and dry-out, toxic chemicals such as chlorine, suffocation by oxygen depletion, treatment with hot water, and biological controls. Each method has benefits and drawbacks, and the specific circumstances will affect which option(s) can be applied. However, most chemical, thermal and low oxygen treatments are restricted to use within industrial and municipal utility facilities. Biological controls are unlikely to result in eradication, and drawdown may have many other

undesirable consequences. Physical removal is the preferred choice, but is not applicable on a large scale.

10. Educating user groups about the impacts of zebra mussels, and giving them the ability to identify suspected mussels and contact the appropriate authorities is critical. Literature should be developed and handed out with each fishing license sold and each boat registered within the Commonwealth. Along with the education literature, warming signs should be posted in areas with high traffic to inform the public of the dangers of zebra mussels.

References

Claudi, R., and G. L. Mackie. 1994. Practical Manual for Zebra Mussel Monitoring and Control. Lewis Publishers, Ann Arbor, Michigan. 11-90.

Karatayev, A. Y., L. E. Burlakova, and D. K. Padilla. 2002. Impacts of Zebra Mussels in Aquatic Communities and Their Role as Ecosystem Engineers. Pages 433-446 in Erikki Leppakoski, Stephan Gollasch and Sergej Olenin, editors. Invasive Aquatic Species of Europe, Distribution, Impacts, and Management. Kluwer Academic Publishers, London, England.

Ludyanskiy, M. L., D. McDonald, and D. MacNeill. 1993. Impacts of the zebra mussel, a bivalve invader. BioScience 43(8):533-544.

Marsden, J. E. 1992. Integrated Pest Management in Freshwater Systems – Lessons for the Zebra Mussel Invasion in North America. Pages 109-116 in World Fisheries Congress, author. Protection of Aquatic Biodiversity: Proceedings of the World. Science Publishers, Lebanon, New Hampshire.

Moser, F. C. 2002. Invasive Species in the Chesapeake Bay Watershed. Zebra Mussel Draft Management Plan. Workshop to Develop Regional Invasive Species Management Strategies, Baltimore, Maryland.

O'Neill, C. R. Jr., and D. B. MacNeill. 1991. The Zebra Mussel (*Dreissena polymorpha*): An Unwelcome North American Invader. Online at www.cce.cornell.edu.

Ram, J. L., P. P. Fong, and D. W. Garton. 1996. Physiological aspects of zebra mussel reproduction: Maturation, spawning, and fertilization. American Zoology 36:326-338.

Spencer, S. L., and K. D. Getsinger. 2002. Zebra mussel chemical control guide, ERDC/EL TR-00-01, U.S. Army Research and Development Center, Vicksburg, Mississippi. Online at http://el.erdc.usace.army.mil/zebra/pdf/trel00-1.pdf