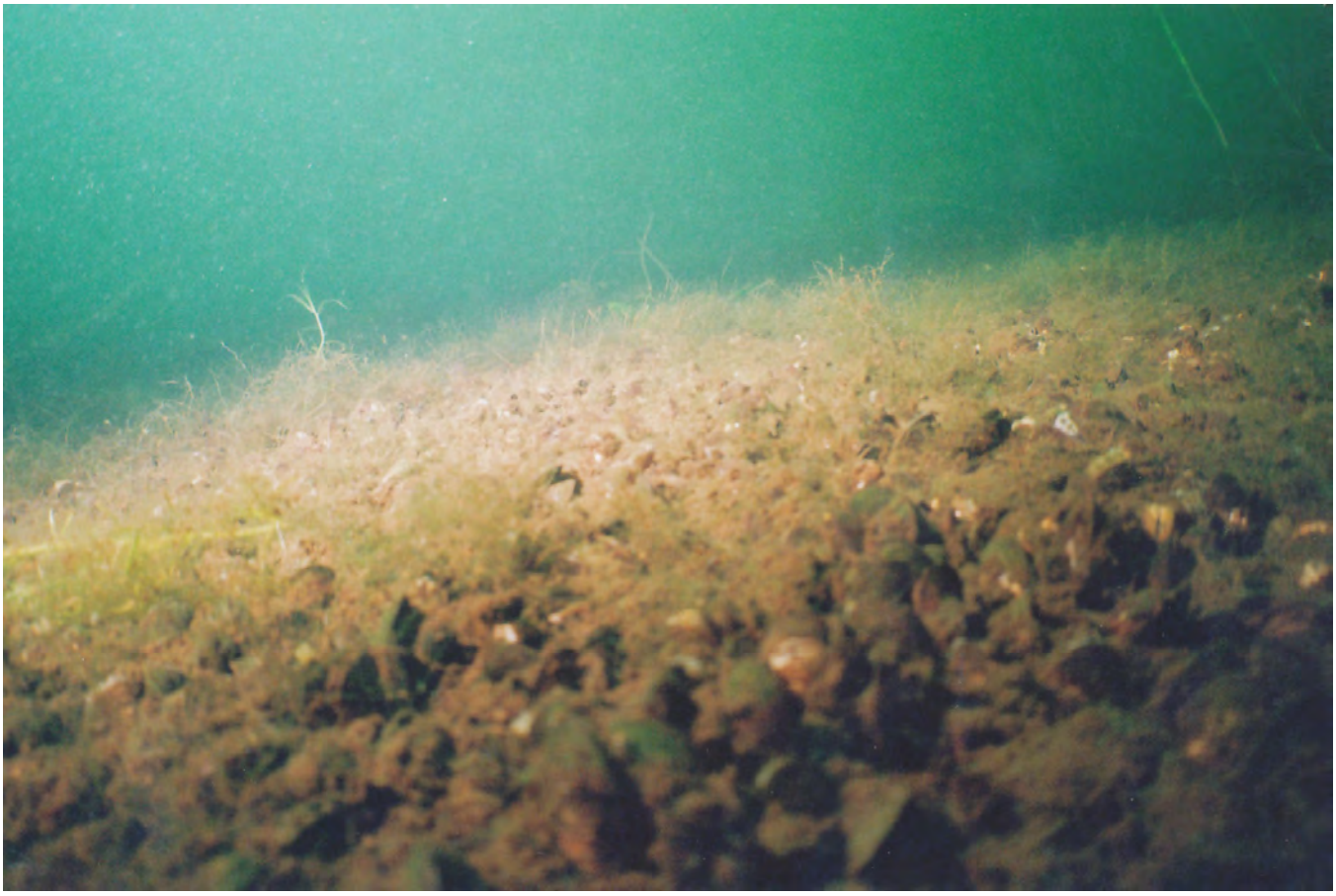

Zebra Mussels Growing on Bottom Sediments of Lake Ossawinnamakee in 2012

Zebra Mussel Early Detection, Rapid Response, and Control Plan for Lakes in Ramsey County, Minnesota

Prepared for:
Ramsey County Parks and Recreation Department
Maplewood, Minnesota

Prepared by:
Steve McComas
Blue Water Science
St. Paul, MN 55116

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Zebra Mussel Early Detection, Rapid Response, and Control Plan for Lakes in Ramsey County, Minnesota

Summary

In 2015, zebra mussels were not found in the twelve lakes surveyed in Ramsey County in a program sponsored by the Ramsey County Park and Recreation Department.

Inspection and prevention programs are the foundation for aquatic invasive species (AIS) comprehensive management programs, and represent an important component of an AIS management program. However there are other components to an AIS management program as well which include early detection, rapid response, and control. Steps to consider for early detection, rapid response, and control components are summarized below.

Early Detection Program

Ramsey County website information and citizen reporting: Create a tab on the Ramsey County website for zebra mussels, construct a zebra mussel identification page (zebra mussels and zebra mussel look-a-likes) to help lake residents identify zebra mussels. Set-up a network for citizen reporting of any zebra mussel observation. Designate a Ramsey County contact person, email address, phone. At a minimum install a zebra mussel plate sampler at each of the public accesses. Installation of an additional 4-6 zebra mussel plate samplers around the each lake is encouraged. Promote monthly lake resident dock and boatlift zebra mussel inspections and also when structures are removed for the season. As lake buoys are removed after the boating season, inspect all buoys and report the presence or absence and lake location of any zebra mussels to the Ramsey County website.

Enhanced zebra mussel early detection search programs: Conduct a training session in June for volunteer searchers. Contract for monthly searches using scuba diving, snorkeling, and wading from July-October. If zebra mussels are found, verify with MnDNR. Produce a press release and notify lake residents.

Rapid Response Program

Rapid response assessment: After the first observation of a zebra mussel in a Ramsey County Park Lake, conduct an assessment effort. Contractors, MnDNR, and others can conduct an initial search in the most probable locations to determine the distribution of zebra mussels. Up to 100 hours of surveying should be considered for a thorough assessment. The zebra mussel search can use divers with up to 10 searchers for 2 days. All zebra mussel locations should be mapped.

Rapid response action: If only 1 or 2 zebra mussel sites are found after the rapid response assessment then eradication could be attempted. The feasibility of a successful eradication should be evaluated by comparing conditions to other lakes that have attempted eradication treatments. Ramsey County would likely coordinate and participate in meetings and aid in decision making to determine if a rapid response action should go forward.

For rapid response action, use copper sulfate for treatment. Containment barriers should be installed and treatment should occur within a confined area. MnDNR permits are necessary and meetings should be conducted prior to zebra mussel arrival. The estimated treatment cost is approximately $8,000 per treatment acre (monitoring and evaluation costs would be additional at approximately $1,000 - $2,000 per site).

Findings and results of the early detection and rapid response program should be summarized in a report.

Additional Details for a Ramsey County Rapid Response Action

The preferred rapid response action for Ramsey County is the use of copper sulfate in a confined treatment area. A summary of other actions that were considered is shown in Table S1.

Table S1. Rapid response action options for a new infestation of zebra mussels in Ramsey County (at a public access area).

Rapid Response Action	Pros	Cons	Costs for a 0.5 acre Treatment (22,000 square feet)
1. EarthTec (copper sulfate compound)	**Used in Christmas and Independence and results are pending. Registered for zebra mussel control.**	**Less than 100% mortality of zebra mussels. Other organisms will be killed. Public access will be closed for a month.**	**Containment barrier up to 8 applications over a 4-5 day period Total: $10,000**
2. Potash (potassium chloride, a molluscicide)	Proven technique in a Virginia quarry and in Lake Winnipeg harbors. Can achieve 100% mortality.	Not a registered pesticide. Need special permission to use it Public access will be closed for a month.	Containment barrier and single treatment: **Total: $8,000**
3. Zequanox (biopesticide)	Proven technique. Used in Christmas Lake. Registered to use for zebra mussel control.	Less than 100% mortality of zebra mussels. Public access will be closed for a month.	Containment barrier and product: **Total: $44,400**
4. Tarp or Pond Liners	Used in Lake Waco, Texas and Lake Tahoe, Nevada (Asian clams). Access remains open.	Need to remove tarps after a month. Need special permits. Organisms under the tarp will be killed.	$1/sf x 22,000 sf = $22,000 + labor **Total: $22,000**
5. Sand Blanket (3 to 6 inches of sand added to area)	No chemicals needed. Access remains open. Theoretical 100% mortality.	Still experimental and untested.	$0.65 sf for 6 inch thickness **Total: $14,300** $0.33 sf for 3 inch thickness **Total: $7,260** + labor to spread the sand
6. Drawdown (dewater the infested area using a water dam)	Can completely dewater and dry out an infested area for a theoretical 100% mortality.	Other organisms will be killed in dewatered area as well.	Rental for 441 feet of a water dam for a containment area: **Total: $46,000** + labor Purchase of 441 ft of a water dam **Total: $113,000** + labor

Steps for a rapid response action include the following.

1. Before any detection of zebra mussels, the treatment action should be planned because a rapid response to an initial zebra mussel observation is critical. Contact a herbicide applicator for the availability of a containment curtain, and the product, which should be copper sulfate (brand name EarthTec). Also a quote for the cost of the curtain and application should be acquired. For budget purposes assume a 1.0 acre treatment area, with an average depth of 3 feet.
2. After an early detection observation, meet with MnDNR AIS staff to discuss a protocol for assessment and treatment. Does the score of the zebra mussel eradication index make it suitable for an eradication attempt?
3. If treatment is to occur at a public access, determine if it can be closed for a month. Discuss with MnDNR, Ramsey County, Angler Groups, and lake association representatives. Conduct an open meeting to discuss options.
4. After a treatment, a post-treatment evaluation is necessary to determine the effectiveness of an eradication treatment. This protocol is available from the MnDNR. Components will likely include a thorough search of the treatment area, using cages holding zebra mussels that will be exposed during the application, and a post treatment survey of the treatment area.
5. The estimated costs associated with the application and monitoring are $10,000 to $20,000 per treatment site which is dependent on the area of the treatment site.

Table S2. Tasks and assignments for an early detection and rapid response program for Ramsey County, Minnesota.

	Ramsey County	Volunteers	Lake Association	MnDNR	Others	Treatment Contractor	Blue Water Science
Early Detection							
Create website information.	May-Aug						
Designate contact person.	May						
Install plate samplers at public access. Check monthly. Remove in October.	Jun-Oct		Jun				
Conduct training session for volunteer searchers (optional).	Jun	Jun	Jun				Jun
Conduct monthly targeted searches (Jul-Oct).							Apr-Oct
Press release if zm are found.	X		X	X			
Rapid Response Assessment							
Conduct an initial exploratory search after the first report of a zebra mussel observation.	X		X	X			X
Organize and train lake searchers for a full search effort.	X		X				X
Conduct an expanded targeted search with diving.	X	X		X			X
Rapid Response Action							
Meet to determine treatment options. (Does the lake score on the zebra mussel eradication index make this a good candidate?)	X		X	X	X	X	X
Close public access, if necessary.	X		X	X	X		
Set-up containment area.						X	
Treat area within the containment area.						X	
Evaluate treatment.				X			X
Report all findings and results.	X		X	X			X

Figure S1. Rapid response assessment in Christmas Lake in 2014.

Small-Scale Zebra Mussel Controls

If eradication actions are not feasible or unsuccessful, zebra mussels will spread through a Ramsey County lake in a few years. For some situations, small scale control for small areas may be an option to suppress zebra mussel heavy growth.

Currently there are several small-scale zebra removal devices that could work to remove zebra mussels from swimming areas, boat accesses and even sandy fish spawning areas (Figure S2). It will likely take 3 or more years before zebra mussels reach high clumping densities in a lake where removal activities are needed.

Large-Scale Zebra Mussel Control

Zebra mussels have few natural controls and large scale or lakewide treatments are not economically or ecologically ready to implement at this time. However, fish predation may have some suppressing value and techniques to enhance predation impacts should be pursued.

Figure S2. Zebra mussel collection devices for small-scale removal projects. These devices can be used to pick up clumps of zebra mussels.

Zebra Mussel Early Detection, Rapid Response, and Control Plan for Lakes in Ramsey County, Minnesota

Introduction

Except for White Bear Lake, lakes with public access within Ramsey County, Minnesota currently do not have zebra mussels.

If zebra mussels were detected in the any of the lakes, changes could occur. This plan outlines detection and rapid response plans as well as potential changes that could occur if zebra mussels become established.

Early Detection Methods for Zebra Mussels

Since 2010, when zebra mussels were detected in Lake Minnetonka, methods of early zebra mussel detection have been evolving. It is now recognized that finding zebra mussels at an early stage of introduction is challenging (Figure 1). Based on what has been learned from Minnesota experiences, an early detection approach has been formulated.

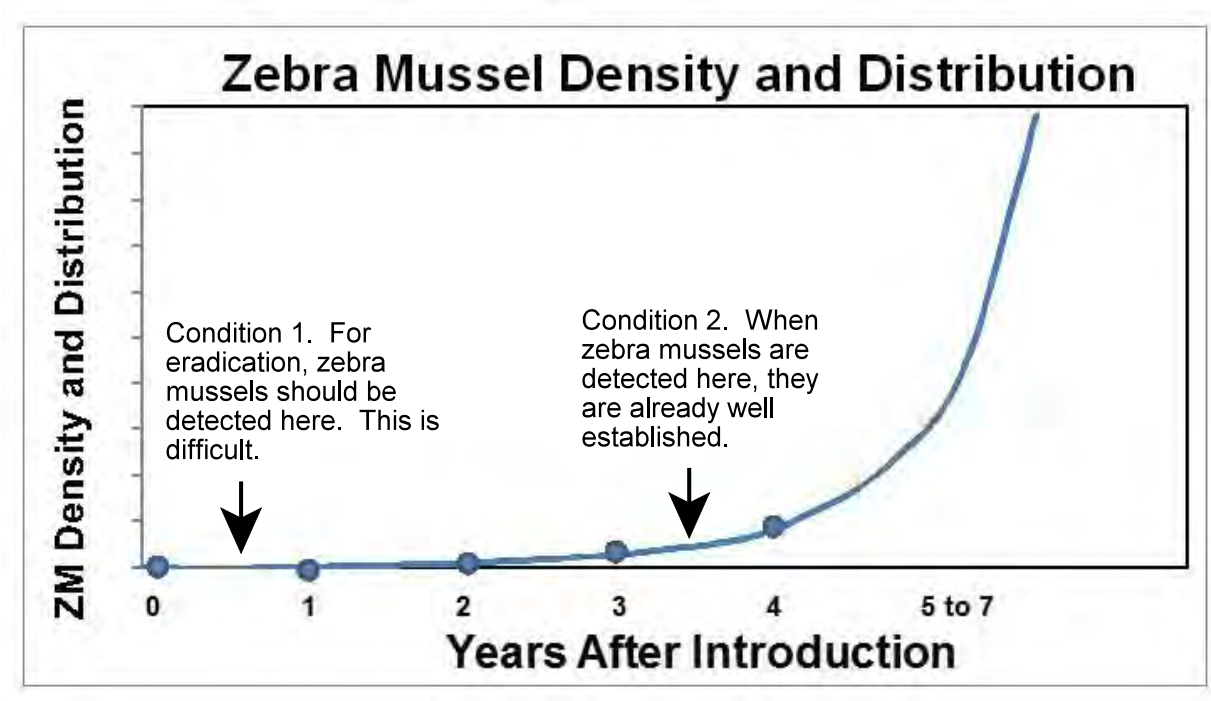
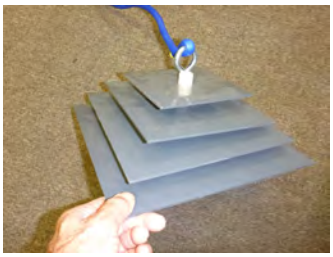


Figure 1. Theoretical zebra mussel growth in a lake (modified from Harvey et al 2009).

Typically, new zebra mussel introductions have come in at a public access or on lake equipment such as boat docks or lifts. The most efficient search effort is inspecting boat landing areas. The probability of finding a new zebra mussel by searching boat lifts and docks around the entire shoreline would be time consuming and inefficient. Unless a lake resident observed an attached zebra mussel on a piece of lake equipment as it goes in, there is little chance of finding this zebra mussel on a random lakewide search of lake equipment. Therefore a search effort should be concentrated in the public access area. Two types of monitoring should be considered at the access: plate samplers and visual inspections.



1. Plate Sampling: An example of a plate sampler consists of 2 to 6 PVC plates spaced about an inch apart and suspended in the water column from a dock or a buoy. Plates can be set out in May and checked monthly or more frequently if desired from June through October. The boat landing area is a high priority site. In addition, citizen volunteers could check their docks monthly over the summer and report findings to the Ramsey County web site.

2. Visual Inspections: Searching for zebra mussels should involve search patterns in nearshore areas around the public access. In early summer cold temperature water, zebra mussel spawning has not yet started, so new veligers would not have settled in areas and developed into juveniles. However, from the previous year, adults may have detached and re-attached on hard substrates in shallow water. Finding new juveniles on hard substrates produced from spawning adults during the growing season might not be detected until July or August when they would be large enough to be observed.

Visual searching has advantages over the use of plate samplers (Christy et al 2010). At low densities, sampling a few high quality target areas with high sampling intensity is more productive than sampling many sites with less intensive sampling (Harvey et al 2009). Rew et al (2006) supports the same detection approach as Harvey et al (2009). Rew et al (2006) reported a targeted transect search was the most efficient method out of seven survey techniques that were tested.

Targeted visual inspections should be conducted in the public access areas. Wading, snorkeling, and scuba diving can be employed. For a high level effort 4 sample days per month are probably necessary. This type of inspection effort could involve 2-4 people for 2 days at 5 hours a day which is equivalent of up to 40 search hours per month. Lower intensity efforts require about 1 day per month from July through October.

In 2014, for zebra mussel detection in White Bear, Green, Independence, and Christmas, searchers examined approximately 2 to 3 objects per minute. In 2014, in numerous searches by Blue Water Science, the lowest frequency of occurrence of zebra mussels was 0.4% or 1 zebra mussel found for 270 objects checked. However, in 2015, a search involving 90 hours that examined 20,000 objects found three zebra mussels.

Therefore, to find a zebra mussel at a low density, a minimum of 7,000 objects may need to be examined to determine if zebra mussels are present or absent.

On a monthly basis, most of the search would be targeted in high probability areas such as boat accesses, areas where drifting veligers may settle, etc. Other sites would get a rapid scan with a smaller time commitment, but covering more sites.

A quantitative search efficiency component should also be considered (summarized in box below).

Quantifying Search Efficiencies: At the lake search areas, either with or without zebra mussels, to get an idea of how efficient a search is, the following methodology can be employed at a search area.

- Select a shoreline length ranging from 50 feet up to 300 feet.
- In shallow water, less than 3 ft deep, randomly disperse 3 to 10 marbles over the bottom substrate.
- Have another searcher go over this area and look for ZMs as well as the targets.
- Searcher collects all targets that are found.
- The results will indicate an approximate search efficiency, If 1 out of 10 targets are recovered, the search efficiency was 10%. If 5 out of 10 targets are recovered the search efficiency was 50%.
- Time of the search and relative density of hard objects should also be recorded.
- The exercise can be repeated for snorkeling search depths (3-5 feet) and for scuba search depths (5-8 feet).

3. Veliger Sampling (optional): As water temperatures warm, monitoring for veliger is a possible method to detect the presence of zebra mussels, but there is a low probability of detecting rare populations when there is a low density of spawning adults (Hoffman et al 2011). Veligers, which are functionally acting like zooplankton, have a low probability of detection (Harvey et al 2009). Veliger monitoring is widely used in the western states and is a technique to be considered in some Minnesota lakes.

Early Detection Summary: The following items are components for an intense zebra mussel early detection program for Ramsey County.

- Install plate samplers at the public access and at 5 to 6 locations in each lake. Samplers should be checked every 3 weeks.
- Set-up a lake resident monthly dock inspection program.
- Conduct visual inspections at the public access monthly, July through October.
- All buoys, docks and boatlifts should be systematically inspected at the time they are removed.

Rapid Response Plan

In previous zebra mussel early detection situations when a zebra mussel population is first observed in a lake, they may have a range from low to moderate density. There is uncertainty where the zebra mussel population is on the growth curve (Figure 1) but it is likely zebra mussels are at Condition 1 or Condition 2 in Figure 1.

A rapid response plan has two components: a rapid response assessment and a rapid response action.

Rapid Response Assessment - What Is the Extent of Zebra Mussel Colonization:

If zebra mussels are discovered in any of the lakes, the next step is to determine the extent of the colonization. This is referred to as rapid response assessment. An intense systematic wading, snorkeling, and scuba survey with a grid pattern to search for the "mother" colony or colonies should be conducted. The area of initial detection should be carefully inspected. In addition, high quality target areas should be selected based on probable dispersal patterns and areas where veligers would land and develop. If the source colony is found, the ZM's should be located with GPS coordinates and removed.

An example of an intense survey to determine the extent of colonization should be considered using up to 10 searchers for two days (at about 5 hours per searcher per day) to search for ZM and cover as much of the high quality areas as possible with available resources. A search efficiency component should be included. This effort would involve up to 100 hours of search time.

The Zebra Mussel Eradication Index: As a component in the rapid response assessment, to help evaluate the zebra mussel status and make a determination if an eradication attempt should be implemented, a semi-quantitative approach can be considered using a Zebra Mussel Eradication Index (McComas, unpublished). The Zebra Mussel Eradication Index has been used for a number of lakes. The highest score recorded to date was for Christmas Lake where an Index score of 730 out of a possible 1,000 points was calculated (Table 1). This has been the best candidate for a zebra mussel eradication attempt as of October 2015. However zebra mussels were found in October 2015 in Christmas Lake three months after the final eradication attempt. Eradication was not successful in Christmas Lake. This indicates that for a successful eradication, an Index score above 730 may be required.

Table 1. Example of a Zebra Mussel Eradication Index worksheet and index scores for Christmas Lake (prepared October 2015).

CHRISTMAS LAKE Criteria	Scores for the Zebra Mussel Eradication Index		
	Poor 0 - 30	Fair 30 - 60	Excellent 60 - 100
1. Minimum of 30 hours and 7,000 objects checked monthly in early detection surveys. Plate or tube samplers should be deployed and checked monthly.		**60** (several inspections per year, 1 plate sampler checked monthly)	
2. Monthly early detection inspections indicate zebra mussels came into the lake within a month. Alternatively, there is specific knowledge of a recent introduction on an object (for example recent installation of a used boatlift with zebra mussels).			**90** (checked plate monthly)
3. Rapid response assessment involves up to 90 hours of additional searching and 20,000 objects should be checked.			**70** (80 hours of inspection)
4. Zebra mussels are found at 1 or 2 sites. If three sites or more are found the probability of eradication decreases. Low numbers of zebra mussels should be present at the site of occurrance. If zebra mussel densities are high, the odds increase that they have detached and drifted to other locations.	**20** (1 site, but over 5,000 juvenile ZMs found)		
5. Zebra mussels should be immature. It has to be assumed immature zebra mussels were introduced on objects detached and reattached to new objects. Presence of mature zebra mussels indicates the probability of ongoing spawning.			**90** (only juveniles were observed)
6. Individual mature zebra mussels should be separated by distance. If two or more mature zebra mussels are found in close proximity successful spawning is likely to have occurred and dispersal of veligers and juveniles may be widespread but undetected.			**100** (no adults)
7. Wave action on containment barriers along open stretches of shoreline causes leakage of treatment water and dilution by lake water reducing the chemical concentration of the toxic agent within the containment area. It is best if the containment area is in a secluded location such as a bay or a cove.			**70** (site is in a cove)
8. Treatment area should be at least 3 times larger than known area of distribution at a site. A total area greater than 10 acres will be difficult to administer. Treatment should occur as soon as possible after the rapid response assessment.			**60** (10 acre treatment site)
9. The probability of reintroduction should be low. Is the public access gated, are inspectors present from sunup to sundown, etc? Also do nearby lakes have zebra mussels?			**80** (Gated and inspected. Lake Minnetonka is nearby.)
10. The smaller the lake the better. The odds of a successful eradication for lakes greater than 300 acres in size is low.			**90** (285 acre lake)
Total Score		**730**	

Rapid Response Action - Eradication Techniques: If the results of the rapid response assessment indicate that all zebra mussels are found in a small area and the Zebra Mussel Eradication Index score is suitably high, an eradication attempt may be considered. If zebra mussels are found in 2 or more areas, and there is a low Index score the odds of a successful eradication are low and going forward with a rapid response action should be carefully considered and probably should not occur. A list of rapid response actions are shown in Table 1. It should be noted that once zebra mussels have been discovered in a lake, they have never been eradicated in the Midwest.

The preferred rapid response treatment product for Ramsey County is the use of copper sulfate (Action 1) (Table 2).

Table 2. Rapid response action options for a new infestation of zebra mussels in Ramsey County (at a public access area).

Rapid Response Action	Pros	Cons	Costs for a 0.5 acre Treatment (22,000 square feet)
1. EarthTec (copper sulfate compound)	**Used in Christmas and Independence and results are pending. Registered for zebra mussel control.**	**Less than 100% mortality of zebra mussels. Other organisms will be killed. Public access will be closed for a month.**	**Containment barrier. Up to 8 treatments Total: $10,000**
2. Potash (potassium chloride a molluscicide)	Proven technique in a Virginia quarry and in Lake Winnipeg harbors. Can achieve 100% mortality.	Not a registered pesticide. Need special permission to use it Public access will be closed for a month.	Containment barrier Single treatment **Total: $8,000**
3. Zequanox (biopesticide)	Proven technique. Used in Christmas Lake. Registered to use for zebra mussel control.	Less than 100% mortality of zebra mussels. Public access will be closed for a month.	Containment barrier: $4,400 Product: $40,000 **Total: $44,400**
4. Tarp or Pond Liners	Used in Lake Waco, Texas and Lake Tahoe, Nevada (Asian clams). Access remains open.	Need to remove tarps after a month. Need special permits. Organisms under the tarp will be killed.	$1/sf x 22,000 sf = $22,000 + labor **Total: $22,000**
5. Sand Blanket (3 to 6 inches of sand added to area)	No chemicals needed. Access remains open. Theoretical 100% mortality.	Still experimental and untested.	$0.65 sf for 6 inch thickness **Total: $14,300** $0.33 sf for 3 inch thickness **Total: $7,260** + labor to spread the sand
6. Drawdown (dewater the infested area using a water dam)	Can completely dewater and dry out an infested area for a theoretical 100% mortality.	Other organisms will be killed in dewatered area as well.	Rental for 441 feet of a water dam for a containment area: **Total: $46,000** + labor Purchase of 441 ft of a water dam **Total: $113,000** + labor

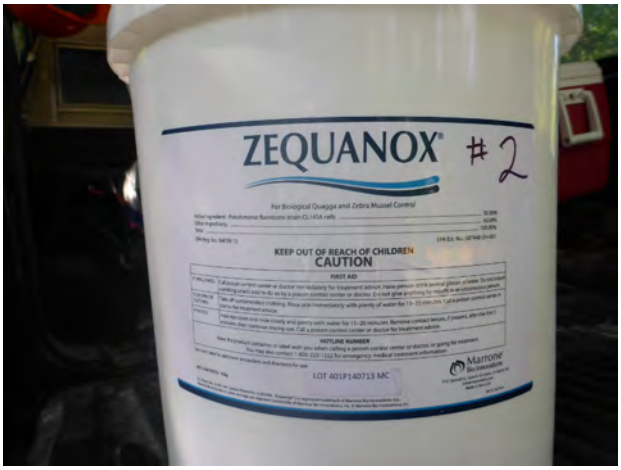
Examples of Rapid Response Actions

1. EarthTec (copper sulfate): Multiple applications necessary to maintain a copper concentrations of 1 ppm. Should be applied within a containment area.


EARTHTEC QZ
Molluscicide for Control of Quagga and Zebra Mussels
WARNING • AVISO
FIRST AID

2. Potash (potassium chloride). Preferred eradication option for a small contained area. Special permission by MnDNR is needed.

3. Zequanox (bio pesticide): Potential to achieve 100% zebra mussel mortality within a containment area.



4. Tarp: prevents feeding and produces low oxygen conditions under the tarp.

(source: Waco Tribune. Lake Waco, Texas. October 21, 2014).

5. Sand blanket: covers zebra mussels and inhibits feeding activities. Untested at this time.

(Source: Lake Charlevoix Association).

6. Dewatering: water dams isolate an area, then the isolated area can be dewatered and dried out.

[left] Water dam used in French Lake, Rice County, Minnesota as a wave barrier
(source: Steve McComas, Blue Water Science).
[right] Water dam used to dewater a small area in a nearshore setting
(source: Hydro Barrier Corp).

Possible Lake Changes if Zebra Mussel Become Established

Ecological and recreational impacts can result from zebra mussel infestations and are summarized below.

Ecological Impacts of Zebra Mussels: With the filtering action of a large population of zebra mussels, water clarity will improve, but there can be changes as a result of this clearer water. Sunlight will penetrate into deeper water and aquatic plants may grow denser and into deeper depths.

Another consideration is that energy flow will be shunted off into a zebra mussel - algal loop and the 'energy' may not flow up to fish. The result could be a lower number of fish. The 'energy' in this case, is the flow of nutrients through the food chain. In lakes without zebra mussels, phosphorus is taken up by algae and algae are grazed by zooplankton, which in turn are eaten by small fish. Gamefish, like bass and walleyes, eat the small fish. Therefore phosphorus has made it's way into the gamefish or piscivores (Figure 2). However, when high densities of zebra mussels are present in a lake, they feed on algae as well. Because predation on zebra mussels by fish is low, the phosphorus 'energy' does not go up the food chain. Instead of transferring energy up to fish, zebra mussel excretion products deposit nutrients into the sediments. Released nutrients from the sediments will go back into algal growth, which in turn, is filtered by zebra mussels, forming the zebra mussel-algal loop. Fish do not get the full benefit of the phosphorus 'energy' component and the result can be lower fish biomass in the long term.

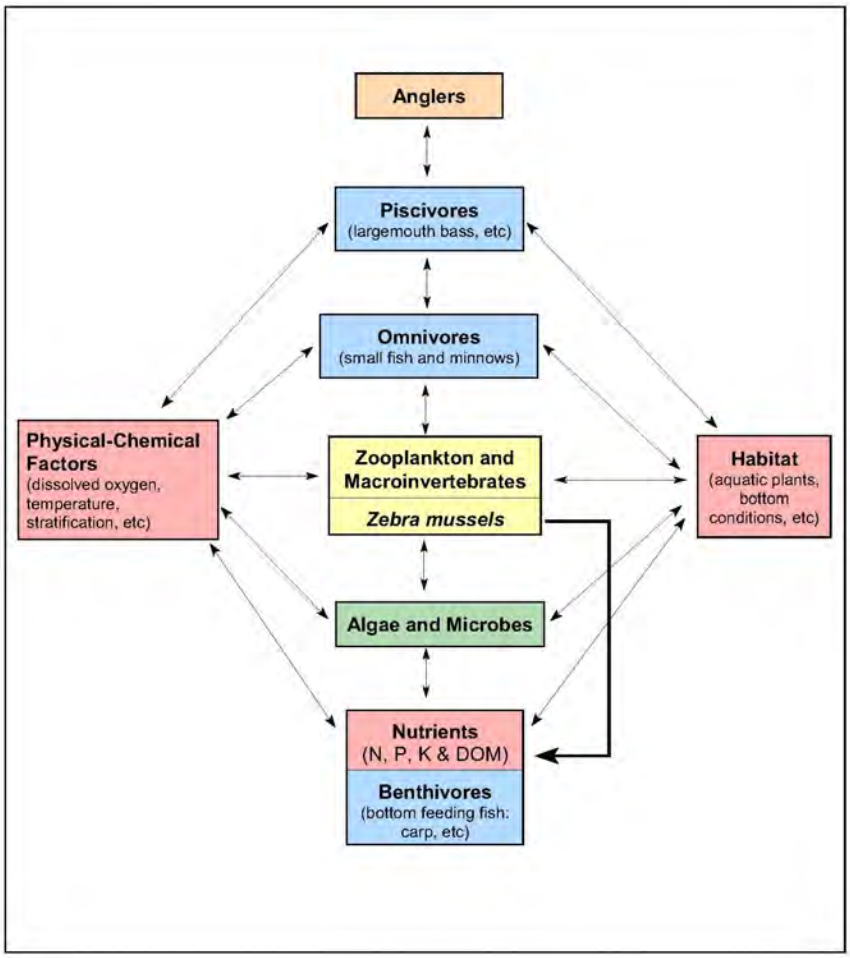


Figure 2. Web of lake interactions (including the zebra mussel loop).

Figure 3. Clear water, as a result of zebra mussel filtering action, may enhance submerged plant growth.

Figure 4. Filamentous algae growth in the bottom of a lake that has zebra mussels. Nutrient rich waste products deposited by zebra mussels on the lake bottom could produce algae growing on sediments.

Recreational Impacts of Zebra Mussels: as the zebra mussel population increases in a lake, there will be additional maintenance activities compared to lakes without zebra mussels. Some of the possible maintenance tasks are shown below.

Zebra mussels on docks and boat lifts will have to be scraped off.

Water intakes can get clogged and zebra mussels should be removed.

Zebra mussels will attach and grow in large and small diameter pipes and water lines.

Zebra mussel shells are sharp and in some cases protective footwear is recommended to protect wader's feet from the shells. However, these conditions don't develop in every lake.

Future Small-Scale Zebra Mussel Control Techniques After Colonization

If eradication actions are not feasible or unsuccessful, zebra mussels will spread through a lake in a few years. For some sites, small scale control for small areas may be an option.

In lakes, the optimal bottom conditions for zebra mussels are rock or wood substrate. These conditions are relatively minor in most lakes. Silt, sand, and muck are the most common type of bottom substrate. Although this type of substrate is suboptimal, zebra mussels will still grow on top of these sediments. As zebra mussel numbers increase, they will start attaching to other zebra mussels, forming clumps of zebra mussels about the size of golf balls. This clumping will be the dominant growth form and zebra mussel clumps will rest on top of the sediments (Figure 5). Zebra mussels will also attach to the stems of aquatic plants (Figure 6).

Figure 5. Zebra mussel clumps sitting on top of a sandy bottom.

Figure 6. Zebra mussels were attached to Sagittaria stems.

Zebra mussels have few natural controls and large scale or lakewide treatments are not economically or ecologically ready to go at this time. The alternative is to control zebra mussels in small areas. Currently there are several small-scale zebra removal devices that could work to remove zebra mussels from swimming areas, boat accesses and even sandy fish spawning areas (Figure 7). It will likely take 3 or more years before zebra mussels reach high clumping densities in a lake where removal activities are needed.

Figure 7. Zebra mussel collection devices for small-scale removal projects. These devices can be used to pick up clumps of zebra mussels.

Ramsey County Small Scale Control Projects

Currently there are several small-scale zebra removal devices that could work to remove zebra mussels from swimming areas, boat accesses and even sandy fish spawning areas. It will likely take 3 or more years before zebra mussels reach high clumping densities in a lake where removal activities are needed.

Whole Lake Zebra Mussel Control Techniques

Whole lake eradication of an established zebra mussel population in a lake over 100 acres has never occurred in the United States. Therefore, whole lake management to control or suppress high densities rather than eradicate 100% of the zebra mussels is more practical. Even with control efforts, zebra mussel declines are usually temporary and populations rebound in a few years. Therefore low cost efforts that are ecologically acceptable have the highest priority as whole lake control techniques. The recommended option for Ramsey County is the fish predation option.

Fish Predation: Fish appear to exert some control over zebra mussels in their native region. Fish have the potential to provide some zebra mussel control but it is untested and undocumented at this time. Fish predation could possibly suppress zebra mussel growth but would not eradicate zebra mussels. Fish predation has the potential to be a low cost and ecologically sound solution and should be pursued.

Drawdown: Lowering the lake level and exposing lake sediments will kill exposed zebra mussels. However, even complete drawdowns have not resulted in complete zebra mussel eradication. The unintentional impacts are significant. A partial drawdown of 3 to 6 feet might be feasible. Adverse impacts would be minimal and some suppression of zebra mussels in shallow water would occur.

Chemical Treatments: The use of potash or copper sulfate as a whole lake treatment is not likely feasible. For copper sulfate the goal is to maintain 1 ppm copper concentration for 4 days and requires repeated doses of copper sulfate to maintain the 1 ppm-Cu concentration. Still, the likelihood of 100% mortality is low. Potash requires a target concentration of 100 ppm-K and there are unintended side-effects on a long-term (months to years) on native mollusks.

Zequanox: Theoretically, a whole lake treatment could be done, but a large quantity of product would be necessary and it would be expensive ($20,000 - $30,000/ac). The likelihood of 100% zebra mussel mortality is low so this would be a suppressive project, not an eradication project. Zequanox is better suited for small scale applications.

Ramsey County Large Scale Control Projects

Fish Predation: Fish appear to exert some control over zebra mussels in their native region. Fish have the potential to provide some zebra mussel control but it is untested and undocumented at this time. Fish predation could possibly suppress zebra mussel growth but would not eradicate zebra mussels. Fish predation has the potential to be a low cost and ecologically sound solution and should be pursued.

Long Term Monitoring for Lakes After Zebra Mussel Colonization

Currently, routine water quality sampling occurs for the major lakes in the Ramsey County lakes. Water quality monitoring is scheduled to continue at these sites in the future. Monitoring zebra mussel densities should be considered as well at these water quality sampling locations. In the future, zebra mussel densities could be correlated with water quality results. In addition, plant assessments and fish surveys will continue and potential changes may be associated with zebra mussel densities.

Figure 8. A clump of zebra mussels being held by Steve McComas. Zebra mussels can colonize on the shells of dead zebra mussels creating "clumps".

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