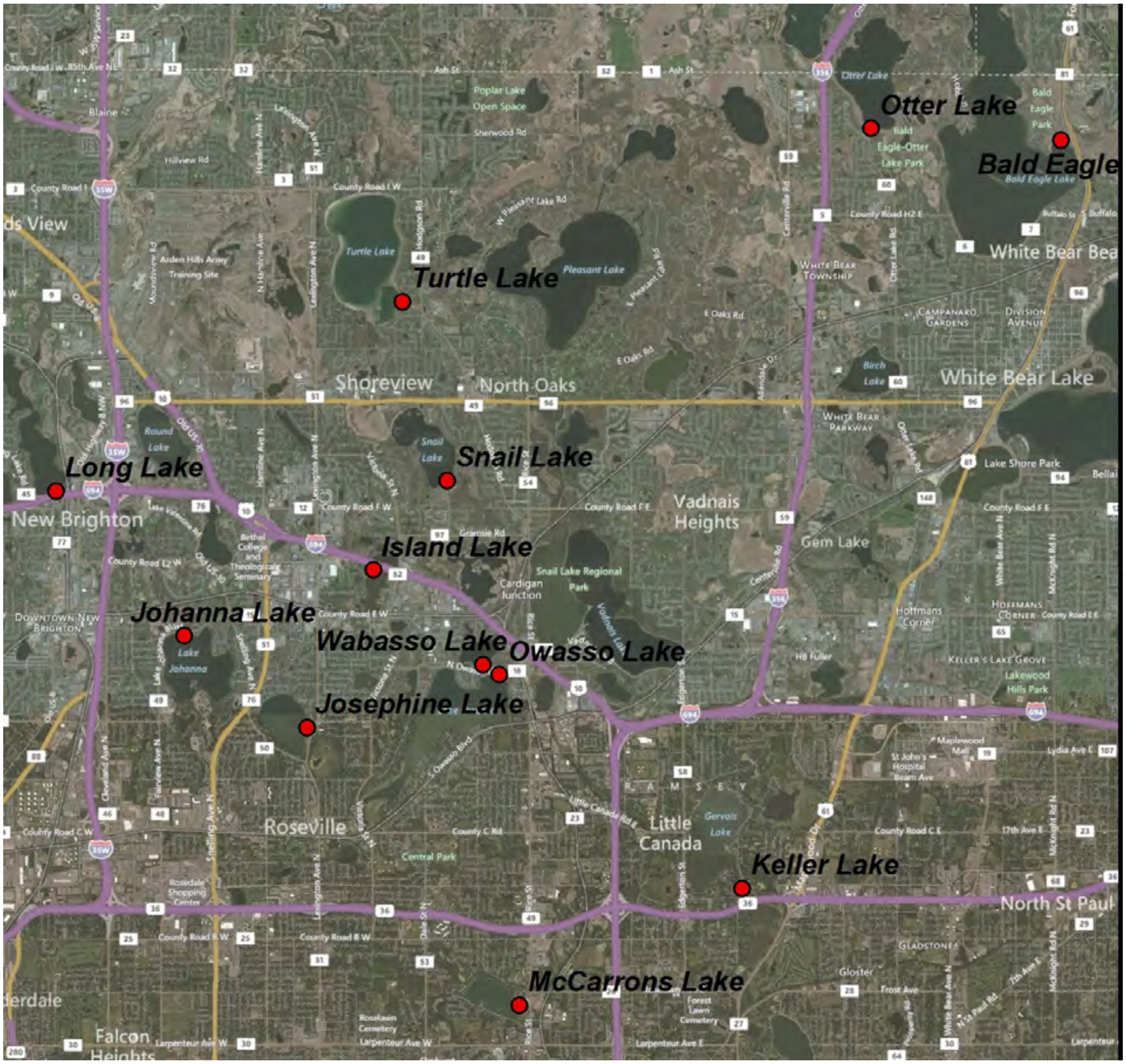

Ramsey County Lakes Checked for Zebra Mussels in 2015

Zebra Mussel Early Detection Surveys and Habitat Suitability at Twelve Ramsey County Lakes in 2015

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Zebra Mussel Early Detection Surveys and Habitat Suitability at Twelve Ramsey County Lakes in 2015

Summary

Public accesses at twelve Ramsey County lakes (Figure 1) were surveyed for zebra mussels in August and September of 2015.

No zebra mussels were found at any of the landing areas at the public access.

The twelve lake public accesses that were inspected include:

- Bald Eagle Lake
- Island Lake
- Lake Johanna
- Lake Josephine
- Keller (Spoon) Lake
- Long Lake
- Lake McCarrons
- Otter Lake
- Lake Owasso
- Snail Lake
- Turtle Lake
- Lake Wabasso

A summary of the search results is shown in Table S1.

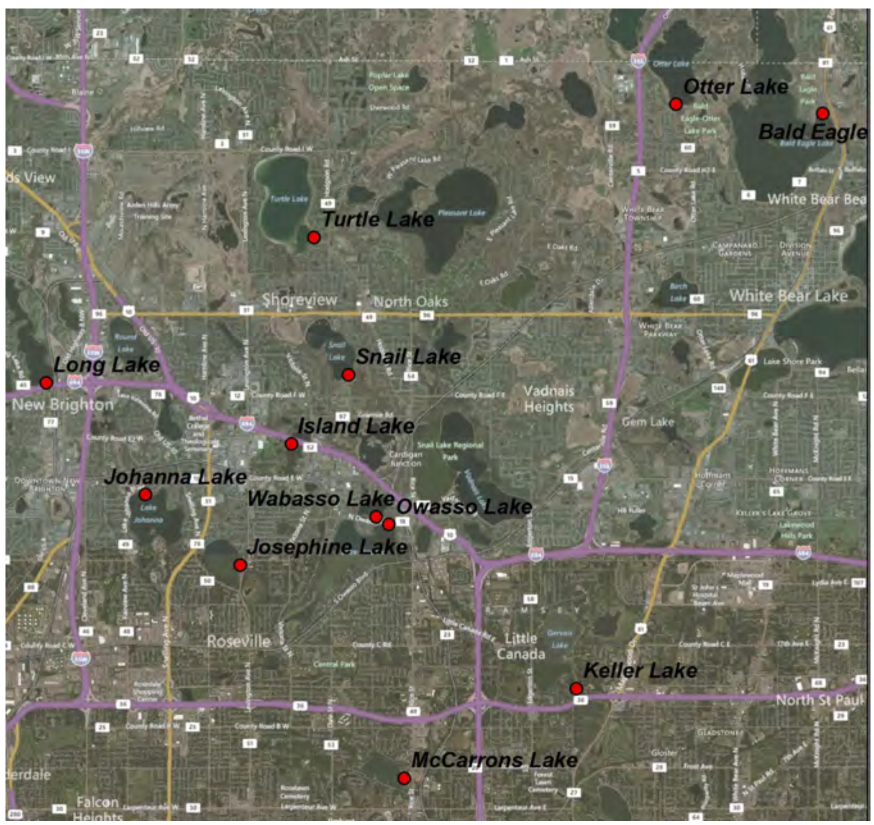


Figure S1. Locations of the 12 Ramsey County lakes inspected for zebra mussels.

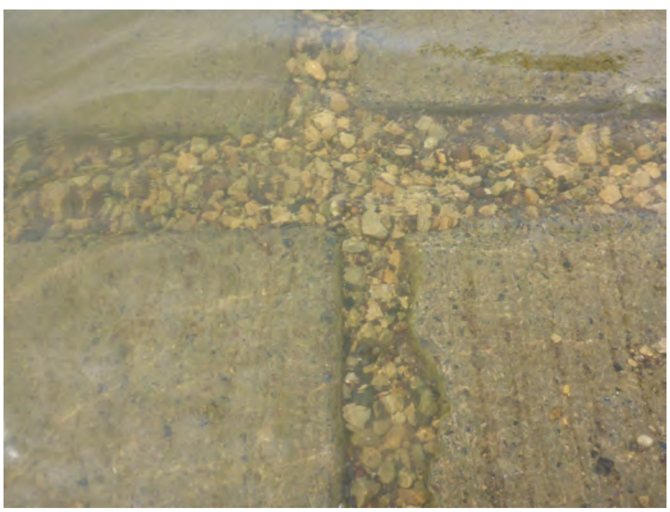
A summary of the search time, objects examined, area searched, and search efficiency are shown in Table S1. No zebra mussels were observed at any of the twelve lakes that were surveyed.

Table S1. Summary of search results for the twelve Ramsey County lakes.

Lake	Date	Search Time (minutes)	Number of Objects Examined	Length of Shoreline (feet)	Area Searched (square feet)	Efficiency of the Search* (%)	Number of Zebra Mussels Found
Bald Eagle	9.4.15	120	540	300	30,000	10%	0
Island	8.21.15	60	210	350	7,500	10%	0
Johanna	8.17.15	60	240	300	12,000	10%	0
Josephine	8.21.15	60	180	350	10,500	30%	0
Keller	9.8.15	90	450	300	12,000	10%	0
Long	8.17.15	80	240	300	12,000	10%	0
McCarrons	9.8.15	90	360	250	15,000	30%	0
Otter	9.4.15	60	180	60	12,000	60%	0
Owasso	8.21.15	60	240	200	18,000	10%	0
Snail	9.4.15	60	180	300	15,000	70%	0
Turtle	9.415	60	180	300	12,000	30%	0
Wabasso	.8.21.15	60	150	60	9,000	0%	0

* search efficiency is conducted by randomly placing 3 to 10 marbles in a search area. Searchers pick up the marbles that are found in the course of searching for zebra mussels in the area. The number of marbles recovered represents an approximation of search efficiency at a site.

Example of Bottom Conditions at Ramsey County Lakes (more pictures are in Appendix A)



Lake Johanna public access ramp.

Lake McCarrons public access ramp area.

If zebra mussels do get established in any of the Ramsey County lakes, growth suitability based on shell production factors and food factors was evaluated. Potential light growth of zebra mussels is predicted in four lakes and heavy or moderate growth is predicted in the other eight lakes (Table S2).

Table S2. Suitability for zebra mussel growth in the twelve Ramsey County lakes.

Lake	Zebra Mussel Growth Potential	Limiting Factor
Bald Eagle	Moderate then heavy then moderate	A few years ago, inedible blue-green algae would have limited zebra mussel growth. Lake is getting cleaner as a result of the alum treatment.
Island	Light	Inedible blue-green algae will limit growth.
Johanna	Heavy then moderate and then light	Algae population is suitable for initial heavy zebra mussel growth, but algae will decrease as the zebra mussel population increases. Then the heavy zebra mussel growth will decrease due to the decrease in the algae concentration. This will limit zebra mussel growth. However, with zebra mussel numbers down algae will increase and then the zebra mussels will increase again. This cycle may be repeated.
Josephine	Moderate then heavy then moderate or light	Similar situation as Johanna.
Keller	Light	Blue-green algae will limit growth.
Long	Light	Blue-green algae will limit growth.
McCarrons	Heavy then moderate	Similar situation as Johanna.
Otter	Heavy then moderate	Similar situation as Johanna.
Owasso	Light	Blue-green algae will limit growth.
Snail	Heavy then moderate then light	Similar situation as Johanna.
Turtle	Heavy then moderate then light	Similar situation as Johanna.
Wabasso	Moderate then light	Could follow a pattern similar to Johanna.

Light growth

Heavy growth (Lake Minnetonka)

Conclusions: A minimum of at least one hour search at each of the boat landings produces a moderate level of a focused inspection. If zebra mussels are to be detected at an early stage, the boat access areas are a high quality target area to inspect.

Although no zebra mussels were observed at any of the public boat access sites at the twelve lakes that were surveyed, that doesn't mean they are not present. However, when these surveys are combined with other inspection results (buoys, piers, etc that are taken out at the end of the season) there is a fairly high probability that zebra mussels are not present at this time.

Zebra Mussel Early Detection Surveys and Habitat Suitability at Twelve Ramsey County Lakes in 2015

Introduction

Ramsey County, through the Parks & Recreation Department, sponsored surveys to determine the presence or absence of zebra mussels at public access sites on twelve Ramsey County lakes.

The objective of the surveys was to survey for the presence or absence of zebra mussels in Ramsey County Parks and Recreation Department administered boat launch access sites in Ramsey County. In addition, if zebra mussels were to become established in a lake the suitability for zebra mussel growth was evaluated for each of the twelve lakes.

Methods

Blue Water Science conducted surveys to determine the presence or absence of zebra mussels. A single survey was conducted at each of the twelve boat launch access sites within Ramsey County and administered by the Ramsey County Parks and Recreation Department between July and September of 2015. The methods consisted of searching all suitable habitat parallel to shore in both directions from the site of the boat launch access site, up to 300 feet in each direction and out to the maximum rooting plant depth or 100 feet from shore, whichever was closest. Scuba diving was used to survey deeper portions of the area (> 4 feet) and wading or snorkeling was used in shallower areas (< 4 feet). A minimum of 150 objects were inspected, including rocks, wood and other solid objects as well as vegetation for attached zebra mussels. The number of objects that were inspected, the amount of time spent searching, and the amount of area searched were recorded.

The twelve lakes that were surveyed included the following:

- Bald Eagle Lake State Water Access Site
- Island Lake State Water Access Site
- Johanna Lake State Water Access Site
- Josephine Lake State Water Access Site
- Keller Lake State Water Access Site
- Long Lake State Water Access Site
- McCarrons Lake State Water Access Site
- Otter Lake State Water Access Site
- Owasso Lake State Water Access Site
- Snail Lake State Water Access Site
- Turtle Lake State Water Access Site
- Wabasso Lake State Water Access Site

In addition, to help evaluate zebra mussel suitability for a given habitat, a water sample was collected at each site and analyzed for calcium, alkalinity, pH, and conductivity. A chart was then prepared that characterized the suitability of zebra mussel growth for each lake. Also, a generic rapid response plan (a separate report) was prepared that could be adapted to any of the twelve lakes if zebra mussels are discovered.

Results

In 2015, no zebra mussels were observed at any of the twelve Ramsey County lakes in surveys at the public access (Table 1). A summary of activities and results for each public access is shown in Table 1. For all the lakes, at least 150 objects were examined. Bald Eagle Lake had the most intensive search conducted.

Table 1. Summary of search results for the twelve Ramsey County lakes.

Lake	Date	Search Time (minutes)	Number of Objects Examined	Length of Shoreline (feet)	Area Searched (square feet)	Efficiency of the Search* (%)	Number of Zebra Mussels Found
Bald Eagle	9.4.15	120	540	300	30,000	10%	0
Island	8.21.15	60	210	350	7,500	10%	0
Johanna	8.17.15	60	240	300	12,000	10%	0
Josephine	8.21.15	60	180	350	10,500	30%	0
Keller	9.8.15	90	450	300	12,000	10%	0
Long	8.17.15	80	240	300	12,000	10%	0
McCarrons	9.8.15	90	360	250	15,000	30%	0
Otter	9.4.15	60	180	60	12,000	60%	0
Owasso	8.21.15	60	240	200	18,000	10%	0
Snail	9.4.15	60	180	300	15,000	70%	0
Turtle	9.4.15	60	180	300	12,000	30%	0
Wabasso	8.21.15	60	150	60	9,000	0%	0

* search efficiency is conducted by randomly placing 3 to 10 marbles in a search area. Searchers pick up the marbles that are found in the course of searching for zebra mussels in the area. The number of marbles recovered represents an approximation of search efficiency at a site.

Figure 1. Steve McComas of Blue Water Science (left) goes over the survey sheet for Keller Lake with Mike Goodnature, Ramsey County Parks and Recreation Department (on the right).

The details of the search results for each of the twelve lakes are shown in Table 2. The area searched ranged from 7,500 sq feet (Island) up to 30,000 sq feet at Bald Eagle. Keller Lake (Spoon Lake landing) had the highest percentage of rocks and had the highest frequency of object inspection (5 objects/minute). A typical search rate was about 3 objects/minute (Table 2).

Table 2. Zebra mussel early detection inspections at twelve Ramsey County lake accesses in 2015.

	Bald Eagle Sept 4, 2015	**Island Aug 21, 2015**	**Johanna Aug 17, 2015**	**Josephine Aug 21, 2015**
Site description	Public access plates detached	Public access	Public access	Public access
Duration of search at this site	11:44-12:45 = 60 minutes	12:45-1:15 = 30 minutes	1:00-1:30 = 30 minutes	12:00-12:30 = 30 minutes
Number of searchers	2	2	2	2
Total search time	120 minutes	60 minutes	60 minutes	60 minutes
Number of objects (rocks, branches, etc) examined in duration of the search (estimated)	4.5/minute = 540 objects	3.5/minute = 210 objects	4/minute = 240 objects	3/minute = 180 objects
Length of shoreline searched (feet)	300 x 100	250 ft x 30	300 ft x 40	350 feet x 30
Total area searched (square feet)	30,000	7,500	12,000	10,500
Range of water depths	0-6 feet	0-6 feet	0-8 feet	0-6 feet
Total number of zebra mussels found	0	0	0	0
Search methodology	wading and snorkeling	wading and snorkeling	wading and snorkeling	wading and snorkeling
Search efficiency*	1/10 = 10%	1/10 = 10%	1/10 = 10%	3/10 = 30%
Substrate conditions S=sand, SI=silt, M=muck, R=rock				
Depth	*0-2 feet* 2% plants 98% sand	*0-2 feet* 70% plants 30% sand	*0-2 feet* 50% plants 20% rocks 30% sand	*0-2 feet* 5% plants 5% rocks 90% sand
Depth	*2 -5+ feet* 90% plants 2% rocks 8% sand	*2-4 feet* 80% plants 20% sand	*2-4 feet* 60% plants 5% rocks 35% sand	*2-4 feet* 40% plants 60% sand
Depth	*Landing* 50% concrete 30% rocks 20% sand		*4-8 feet* 90% plants 2% rocks 8% sand	*4-6 feet* 25% plants

* search efficiency is conducted by randomly placing 3 to 10 marbles in a search area. Searchers pick up the marbles that are found in the course of searching for zebra mussels in the area. The number of marbles recovered represents an approximation of search efficiency at a site.

Table 2. Continued.

	Keller (Spoon) Sept 8, 2015	Long Aug 17, 2015	McCarrons Sept 8, 2015	Otter Sept 4, 2015
Site description	Public access	Public access	Public access	Public access
Duration of search at this site	2:00-2:45 = 45 minutes	1:50-2:30 = 40 minutes	45 minutes	1:30-2:00 = 30 minutes
Number of searchers	2	2	2	2
Total search time	90 minutes	80 minutes	90	60 minutes
Number of objects (rocks, branches, etc) examined in duration of the search (estimated)	5/minute = 450 objects	3/minute = 240 objects	4/minute = 360 objects	3/minute = 180 objects
Length of shoreline searched (feet)	300 x 40	300 x 40	250 x 60	60 x 200
Total area searched (square feet)	12,000	12,000	15,000	12,000
Range of water depths	0-7 feet	0-8 feet	0-6 feet	0-7 feet
Total number of zebra mussels found	0	0	0	0
Search methodology	wading and snorkeling	wading and snorkeling	wading and snorkeling	wading and snorkeling
Search efficiency	1/10 = 10%	1/10 = 10%	3/10 = 30%	6/10 = 60%
Substrate conditions S=sand, SI=silt, M=muck, R=rock				
Depth	*0-2 feet* 20% plants 80% rocks	*0-2 feet* 2% plants 98% sand	*0-2 feet* 10% plants 10% rocks 80% sand	*landing* 40% concrete 40% rocks 20% fila algae *side of ramp* 100% cattails
Depth	*2-6 feet* 20% plants 80% rocks	*2-4 feet* 70% plants 30% sand	*2-6 feet* 70% plants 5% rocks 25% sand	
Depth	*landing* 60% concrete 40% rock	*4-8 feet* 85% plants 15% sand *end of ramp* 50% concrete 50% rock	*landing* 60% concrete 10% rock 30% sand	

* search efficiency is conducted by randomly placing 3 to 10 marbles in a search area. Searchers pick up the marbles that are found in the course of searching for zebra mussels in the area. The number of marbles recovered represents an approximation of search efficiency at a site.

Table 2. Concluded.

	Owasso Aug 21, 2015	Snail Sept 4, 2015	Turtle Sept 4, 2015	Wabasso Aug 21, 2015	White Bear Sept 4, 2015
Site description	Public access	Public access	Public access	Public access	Public access
Duration of search at this site	30 minutes	3:00-3:30 = 30 minutes	2:15-2:45 = 30 minutes	30 minutes	1:00-1:20 = 20 minutes
Number of searchers	2	2	2	2	2
Total search time	60 minutes	60 minutes	60 minutes	60 minutes	40 minutes
Number of objects (rocks, branches, etc) examined in duration of the search (estimated)	3/minute = 240 objects	3/minute = 180 objects	3/minute = 180 objects	2.5/minute = 150 objects	2/minute = 80 objects
Length of shoreline searched (feet)	200 x 90	300 x 50	300 x 40	60 x 150	300 x 50
Total area searched (square feet)	18,000	15,000	12,000	9,000	15,000
Range of water depths	0-6 feet	0-8 feet	0-8 feet	0-6 feet	0-5+ feet
Total number of zebra mussels found	0	0	0	0	0
Search methodology	wading and snorkeling	wading and snorkeling	wading and snorkeling	wading and snorkeling	wading and snorkeling
Search efficiency*	1/10 = 10%	7/10 = 70% (landing/concrete) 0/10 = 0% (muck) 35% (average)	3/10 = 30%	0/10 = 0%	--
Substrate conditions S=sand, SI=silt, M=muck, R=rock					
Depth	*0-2 feet* 90% plants 10% sand	*0-5 feet* 60% plants 5% rocks 35% sand	*0-5 feet* 50% plants 10% rocks 40% sand	*0-2 feet* 100% muck with 90% plants	*0-2 feet* 10% plants 90% sand
Depth	*2-4 feet* 95% plants 5% sand	*5+ feet* 100% muck	*5+ feet* 100% plants	*2-4 feet* 100% muck 100% plants	*5+ feet* 100% plants
Depth	*4-6 feet* 95% plants 5% sand	*landing* 80% concrete 20% rocks	*landing* 80% concrete 15% rocks 5% sand	*4-6 feet* 100% muck 100% plants	*landing* 50% concrete 5% rock 45% sand

* search efficiency is conducted by randomly placing 3 to 10 marbles in a search area. Searchers pick up the marbles that are found in the course of searching for zebra mussels in the area. The number of marbles recovered represents an approximation of search efficiency at a site.

Habitat and Substrate Conditions for Twelve Lakes

A common pattern observed at the public access sites was for areas adjacent to the concrete apron, sand was the dominant substrate from 0 to 2 feet of water depth. Sand is not a good substrate for zebra mussel colonization. Zebra mussels require a firm surface for attachment using their byssal threads. However, there are scattered rocks and gravel that could be used as a substrate for attachment by zebra mussels. The weed line started at 2 or 3 feet of water depth at many of the sites and was the dominant substrate from 2 feet and deeper. Zebra mussels will attach to plant stems but it is not a preferred substrate. Only Otter, Owasso, and Wabasso landings were dominated by aquatic plants in the 0-2 feet depth.

Out of twelve public access sites, Keller Lake had the highest percentage of optimal substrate. At the other lakes, the access area was dominated by sand or by aquatic plants which is considered to be suboptimal substrate. At all the landings, in-between the concrete planks that make up the concrete landing, the surfaces are optimal substrate.

Examples of substrate conditions at all twelve public access sites are shown in Appendix A.

Table 3. Habitat conditions of twelve Ramsey County public access sites. Does not include the concrete planks or the rocks in-between the planks of the concrete ramp.

	Substrate Conditions					
	0 - 2 feet			2 - 6 feet		
	% rocks	% sand	% plants	% rocks	% sand	% plants
Bald Eagle Lake	sparse	98	2	2	8	90
Island Lake	--	30	70	--	20	80
Lake Johanna	20	30	50	5	35	60
Lake Josephine	5	90	5	--	60	40
Keller (Spoon) Lake	80	--	20	80	--	20
Long Lake	--	98	2	--	30	70
Lake McCarrons	10	80	10	5	25	70
Otter Lake	--	--	100	--	--	100
Lake Owasso	--	10	90	--	5	95
Snail Lake	5	35	60	--	100 (muck)	--
Turtle Lake	10	40	50	--	--	100
Lake Wabasso	--	10 (muck)	90	--	--	100

Zebra Mussel Suitability in Ramsey County Lakes

The aquatic invasive species (AIS) framework presents an overview of the types of AIS that can be expected in lakes (Figure 2). The framework indicates some AIS will only survive and not reproduce whereas others will survive and reproduce. In some cases AIS will become invasive. Zebra mussels can cycle between naturalization and invasive conditions depending primarily on the food supply which is primarily algae.

For the twelve Ramsey County lakes, a zebra mussel suitability analysis was conducted using water samples collected in this project and also using available information.

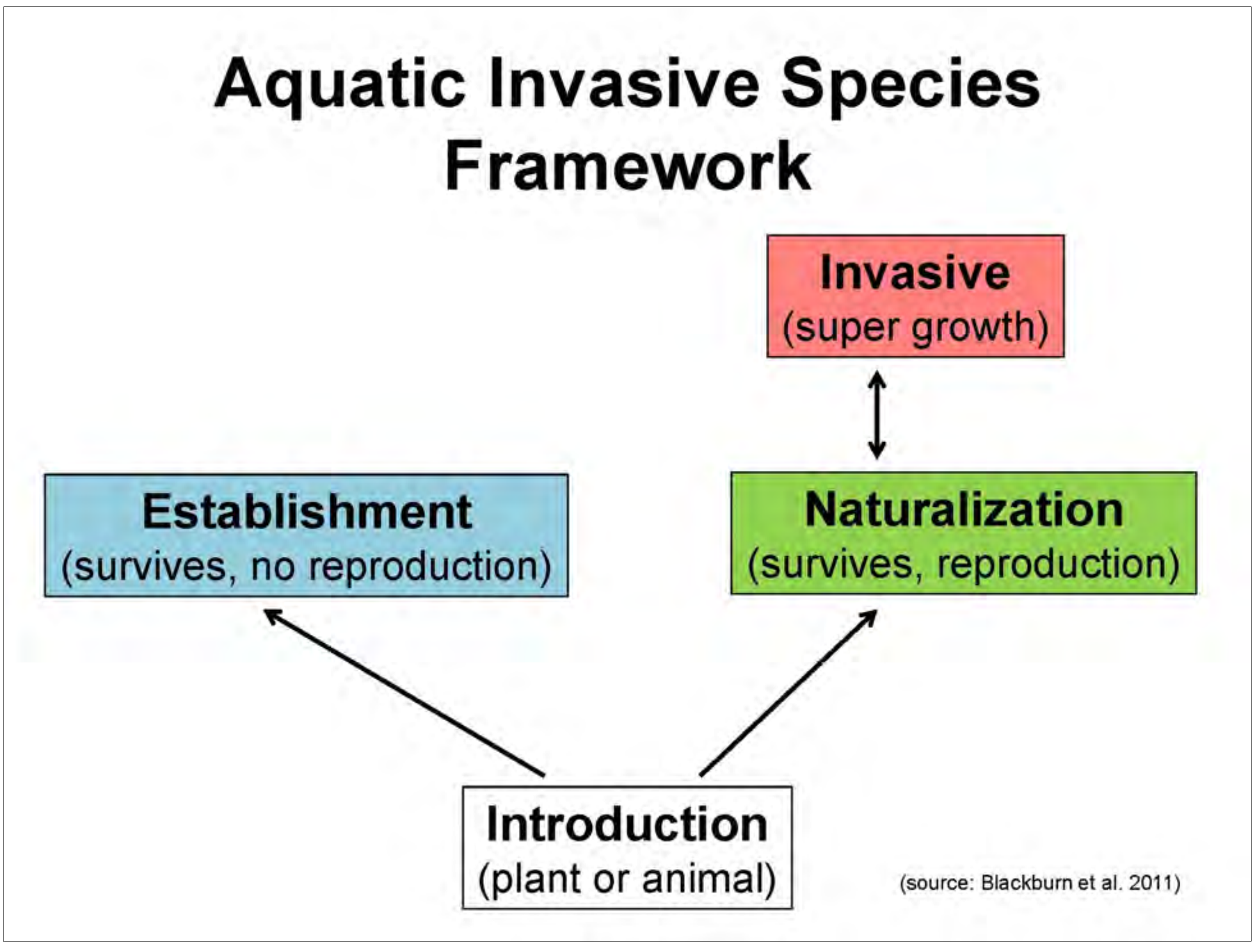


Figure 2. Aquatic invasive species framework (source: Blackburn et al 2011).

A summary of the suitability for zebra mussel growth in each of the twelve lakes is shown in Table 4.

If zebra mussels become established in any of the Ramsey County lakes, growth suitability based on shell production factors and food factors was evaluated. Potential light growth of zebra mussels is predicted in four lakes and heavy or moderate growth is predicted in the other eight lakes (Table 4). Examples of light, moderate, and heavy growth are shown in Figure 3.

Individual suitability tables for each of the twelve lakes surveyed are found in Appendix B.

Table 4. Suitability for zebra mussel growth in the twelve Ramsey County lakes.

Lake	Zebra Mussel Growth Potential	Limiting Factor
Bald Eagle	Moderate then heavy then moderate	A few years ago, inedible blue-green algae would have limited zebra mussel growth. Lake is getting cleaner as a result of the alum treatment.
Island	Light	Inedible blue-green algae will limit growth.
Johanna	Heavy then moderate and then light	Algae population is suitable for initial heavy zebra mussel growth, but algae will decrease as the zebra mussel population increases. Then the heavy zebra mussel growth will decrease due to the decrease in the algae concentration. This will limit zebra mussel growth. However, with zebra mussel numbers down algae will increase and then the zebra mussels will increase again. This cycle may be repeated.
Josephine	Moderate then heavy then moderate or light	Similar situation as Johanna.
Keller	Light	Blue-green algae will limit growth.
Long	Light	Blue-green algae will limit growth.
McCarrons	Heavy then moderate	Similar situation as Johanna.
Otter	Heavy then moderate	Similar situation as Johanna.
Owasso	Light	Blue-green algae will limit growth.
Snail	Heavy then moderate then light	Similar situation as Johanna.
Turtle	Heavy then moderate then light	Similar situation as Johanna.
Wabasso	Moderate then light	Could follow a pattern similar to Johanna.

Examples of Zebra Mussel Growth Conditions

Light Growth | **Moderate Growth (*suboptimal growth*)** | **Heavy Growth (*optimal growth*)**

Figure 3. Light growth (left). Small mussels can colonize on plants or hard substrates but sometimes conditions will limit growth to a single season followed by a zebra mussel die-off at the end of the year. Moderate growth (middle) can be found on soft sediments, in clumps, with zebra mussels attached to each other. Zebra mussels can colonize aquatic plants as well. Heavy growth (right) is found where there are hard surfaces such as rocks, woody structures, or docks and where water column conditions are suitable.

Discussion

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 4). Based on what has been learned from Minnesota experiences, an early detection approach has been formulated.

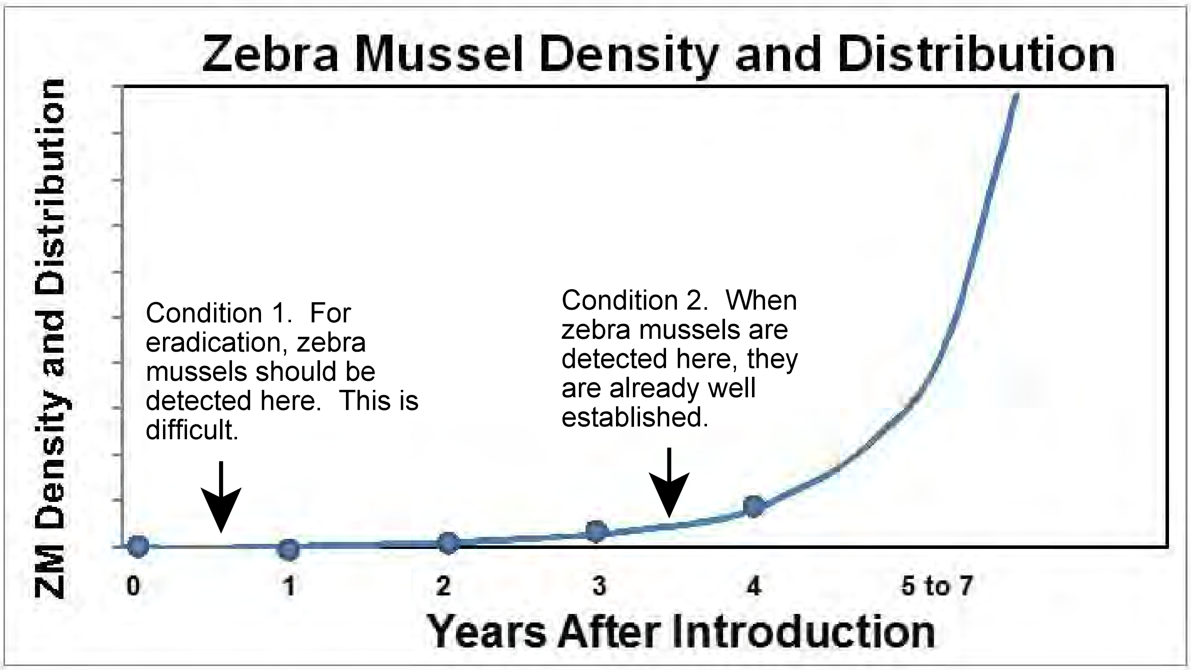


Figure 4. Theoretical zebra mussel growth in a lake (modified from Harvey et al 2009).

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 access 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 and the public access is a high priority area to check. In early summer when water temperatures are below 54°F, zebra mussel spawning has not yet started, so new veligers would not have settled in areas and developed into juveniles. However, over the winter, 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 intensity effort 4 sample days per month are probably a minimum. The 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. 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). Previous zebra mussel surveys have rarely recovered 100% of the targets that were distributed throughout a search area. These results indicate that zebra mussels could be in a search area, but not found.

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: 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.

Conclusions

A minimum of at least one hour search at each of the boat landings produces a moderate level of a focused inspection. If zebra mussels are to be detected at an early stage, the boat access areas is a high quality target area to inspect.

Although no zebra mussels were observed at any of the public boat access sites at the twelve lakes that were surveyed, that doesn't mean they are not present. However, when these surveys are combined with other inspection results (buoys, piers, etc that are taken out at the end of the season) there is a fairly high probability that zebra mussels are not present at this time.

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APPENDIX A

Habitat and Substrate Conditions for Twelve Lakes

1. Bald Eagle



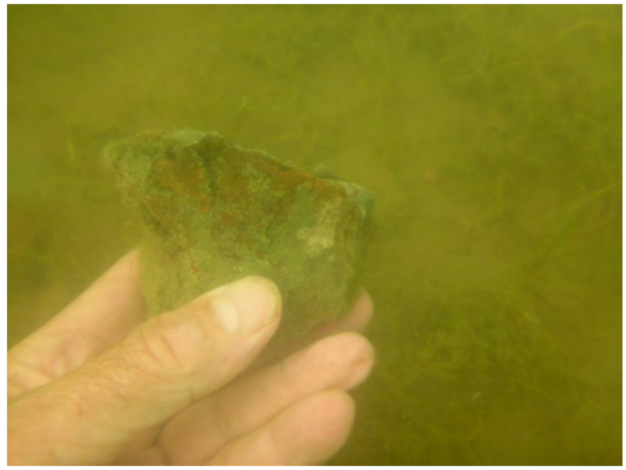
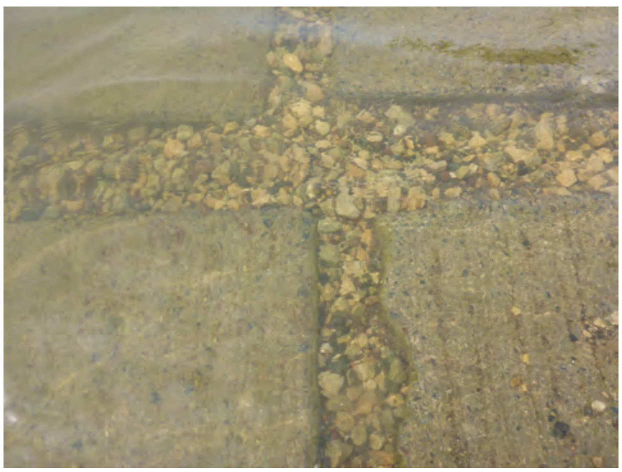



2. Island Lake



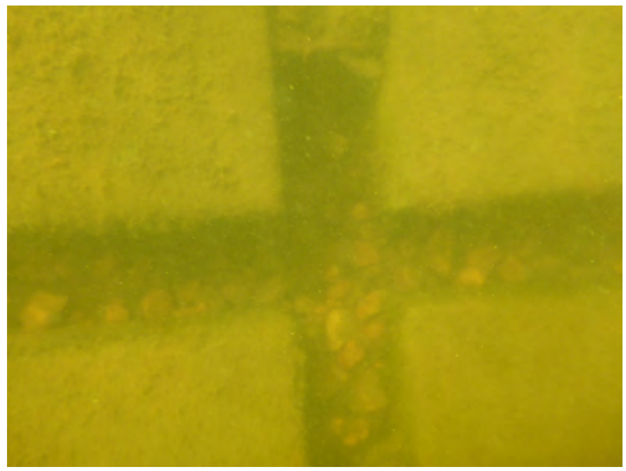


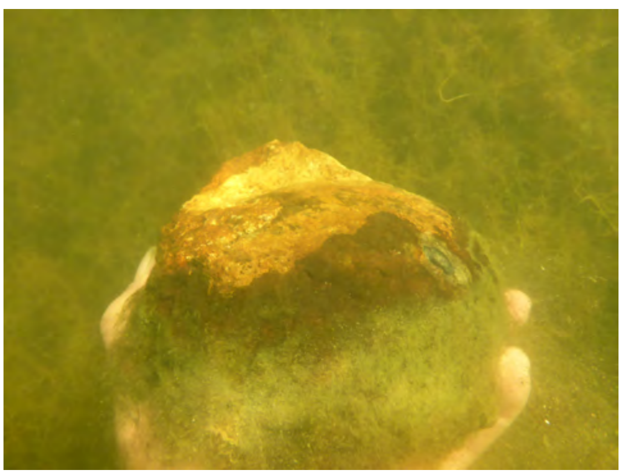

3. Lake Johanna


4. Lake Josephine

5. Keller (Spoon) Lake





6. Long Lake

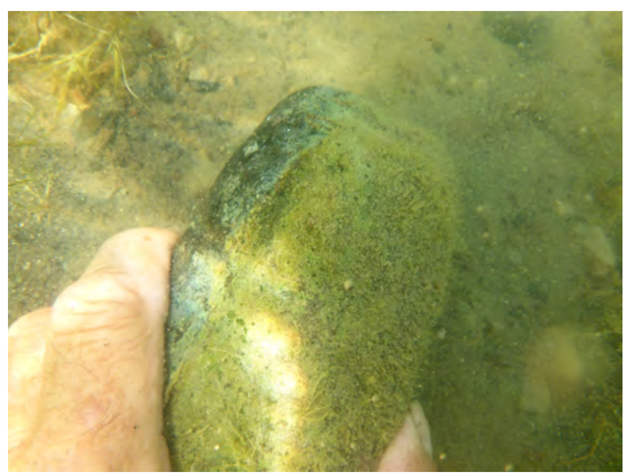




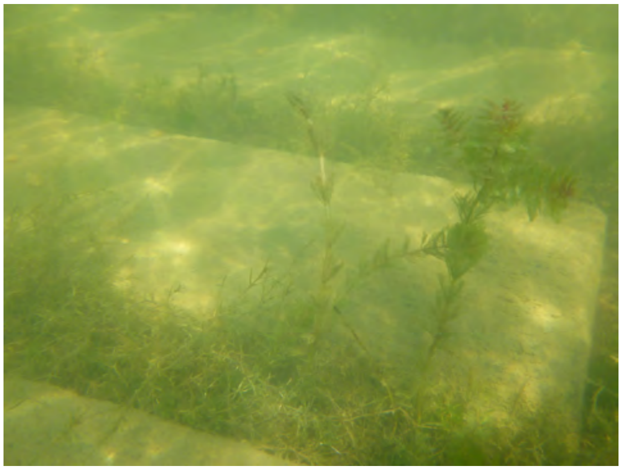

7. Lake McCarrons





7. Lake McCarrons (concluded)



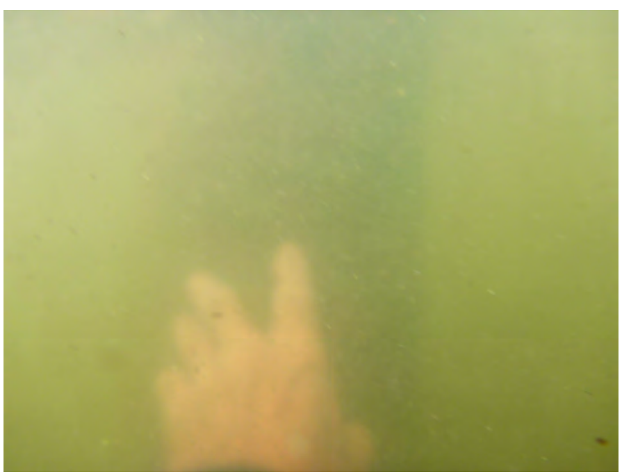
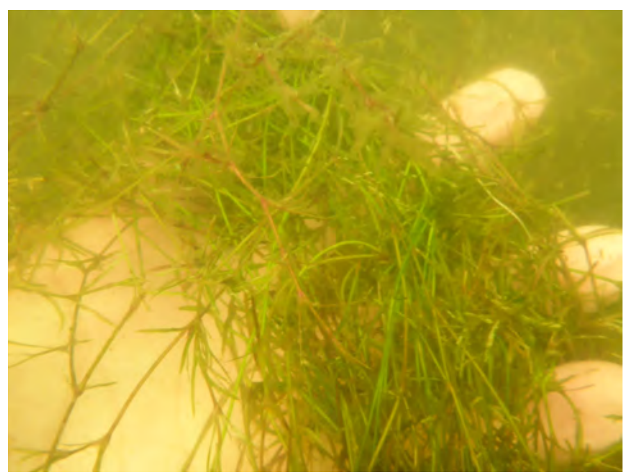



8. Otter Lake

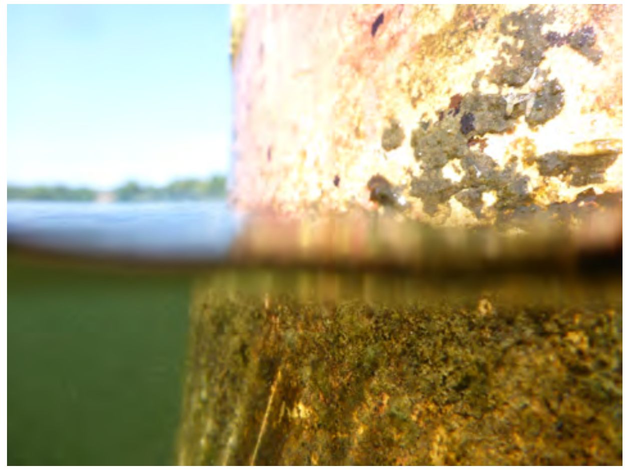
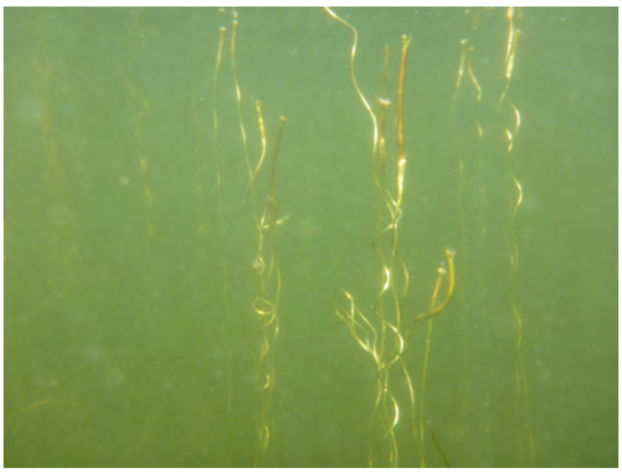
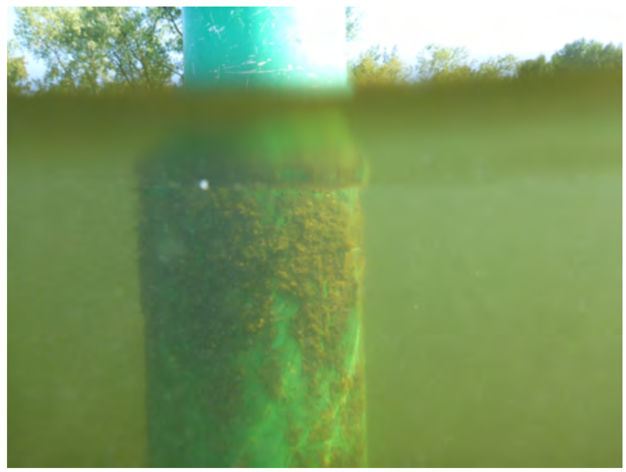
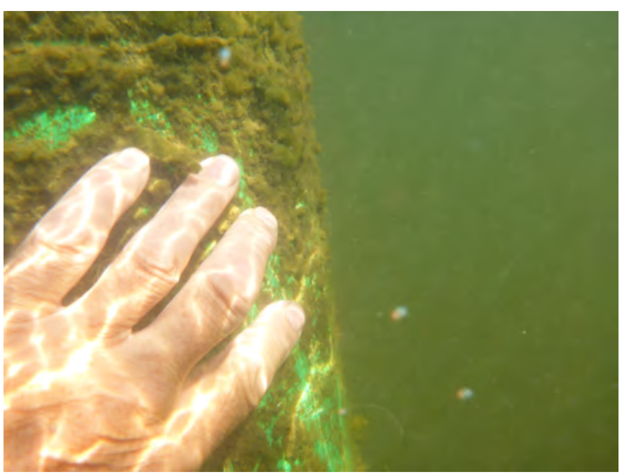
9. Lake Owasso



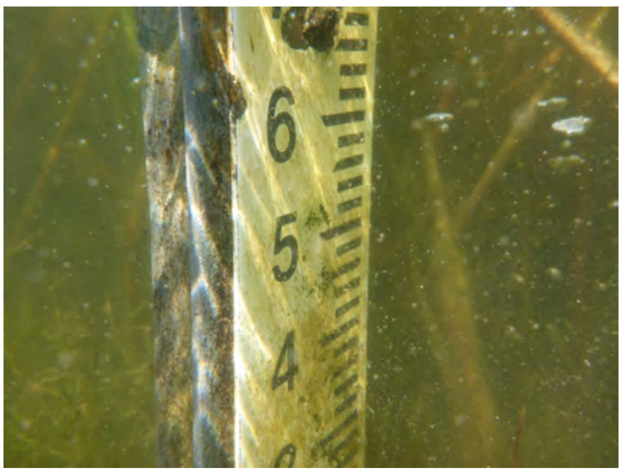


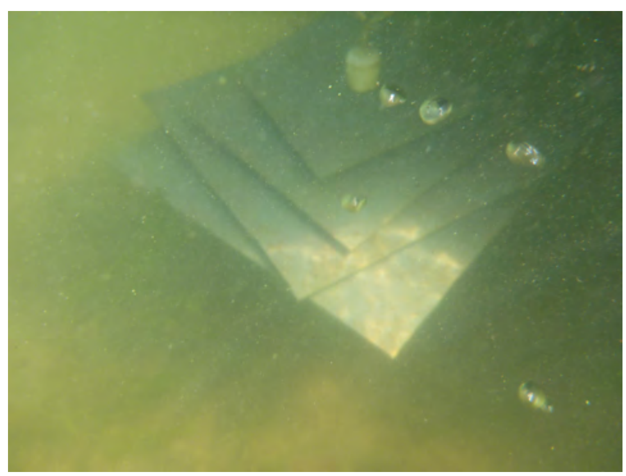



10. Snail Lake

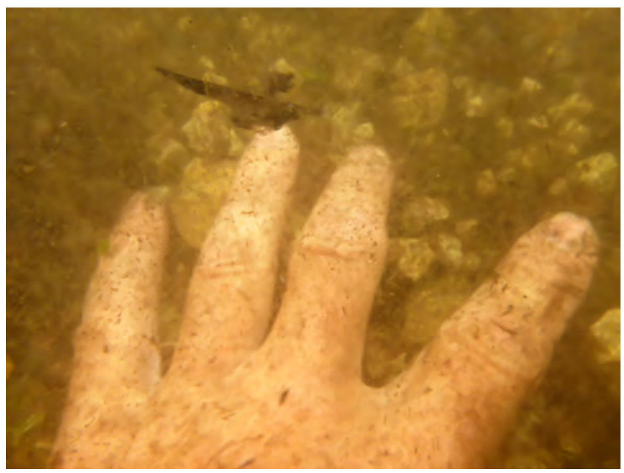







11. Turtle Lake





12. Lake Wabasso



APPENDIX B

Zebra Mussel Suitability for Twelve Lakes

Zebra Mussel Suitability for Bald Eagle Lake uses water column suitability criteria to predict growth conditions.

1. BALD EAGLE		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Bald Eagle				37.7 (9.4.15)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Bald Eagle			7.9 (9.4.15)	
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Bald Eagle				118 (9.4.15)
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Bald Eagle				397 (9.4.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Bald Eagle		1.0 (10 year average)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Bald Eagle	35 (10 year average)			
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Bald Eagle	69 (10 year average)			
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Island Lake uses water column suitability criteria to predict growth conditions.

2. ISLAND		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Island			16.9 (Aug 21, 2015)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Island			8.9 (Aug 21, 2015)	
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Island		52 (Aug 21, 2015)		
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Island				340 (Aug 21, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Island		1 (10 year average)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Island	26 (10 year average)			
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Island	68 (10 year average)			
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Lake Johanna uses water column suitability criteria to predict growth conditions.

3. JOHANNA		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Johanna				31.2 (Aug 17, 2015)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Johanna				8.7 (Aug 17, 2015)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Johanna			71 (Aug 17, 2015)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Johanna				605 (Aug 17, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Johanna		2 (10 year average)		2 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Johanna			11 (10 year average)	
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Johanna				28 (10 year average)
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Lake Josephine uses water column suitability criteria to predict growth conditions.

4. JOSEPHINE		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Josephine				32.2 (Aug 21, 2015)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Josephine				8.5 (Aug 21, 2015)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Josephine			88 (Aug 21, 2015)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Josephine				400 (Aug 21, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Josephine		2 (10 year average)		2 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Josephine			12 (10 year average)	
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Josephine				31 (10 year average)
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Keller Lake uses water column suitability criteria to predict growth conditions.

5. KELLER		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Keller				43.6 (9.11.15)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Keller				8.4 (9.11.15)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Keller				106 (9.11.15)
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Keller				530 (9.11.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Keller		1 (10 year average)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Keller			14 (10 year average)	
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Keller		47 (10 year average)		
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Long Lake uses water column suitability criteria to predict growth conditions.

6. LONG		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Long				39 (Aug 17, 2015)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Long				8.6 (Aug 17, 2015)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Long			96 (Aug 17, 2015)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Long				515 (Aug 17, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Long		1 (10 year average)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Long	37 (10 year average)			
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Long	84 (10 year average)			
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Lake McCarrons uses water column suitability criteria to predict growth conditions.

7. McCARRONS		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	McCarrons				37.5 (9.11.15)
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	McCarrons				8.6 (9.11.15)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	McCarrons				102 (9.11.15)
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	McCarrons				510 (9.11.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	McCarrons				3 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	McCarrons				5 (10 year average)
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	McCarrons			18 (10 year average)	
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Otter Lake uses water column suitability criteria to predict growth conditions.

8. OTTER		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Otter			23.1 (9.4.15)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Otter			7.8 (9.4.15)	
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Otter			74 (9.4.15)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Otter				310 (9.4.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Otter				3 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Otter				3 (10 year average)
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Otter			18 (10 year average)	
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Lake Owasso uses water column suitability criteria to predict growth conditions.

9. OWASSO		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Owasso			22.6 (Aug 21, 2015)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Owasso			8.9 (Aug 21, 2015)	
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Owasso			66 (Aug 21, 2015)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Owasso				300 (Aug 21, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Owasso		1 (10 year average)		
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Owasso		21 (10 year average)		
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Owasso		42 (10 year average)		
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Snail Lake uses water column suitability criteria to predict growth conditions.

10. SNAIL		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Snail			24.4 (9.4.15)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Snail				8.3 (9.4.15)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Snail			74 (9.4.15)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Snail				409 (9.4.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Snail				3 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Snail				4 (10 year average)
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Snail			18 (10 year average)	
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Turtle Lake uses water column suitability criteria to predict growth conditions.

11. TURTLE		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Turtle			28.1 (9.4.15)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Turtle				8.4 (9.4.15)
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Turtle			91 (9.4.15)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Turtle				348 (9.4.15)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Turtle		2 (10 year average)		2 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Turtle				5 (10 year average)
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Turtle			18 (10 year average)	
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

Zebra Mussel Suitability for Lake Wabasso uses water column suitability criteria to predict growth conditions.

12. WABASSO		Little Potential for Adult Survival	Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Shell Formation Factors					
Calcium (mg/l)	Wabasso			24.5 (Aug 21, 2015)	
	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
pH	Wabasso		7.4 (Aug 21, 2015)		
	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Alkalinity* (as mg $CaCO_3$/l)	Wabasso			71 (Aug 21, 2015)	
	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity* (umhos)	Wabasso				280 (Aug 21, 2015)
	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Food Factors					
Secchi depth (m) (May-Sept)	Wabasso				3 (10 year average)
	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source) (May-Sept)	Wabasso			9 (10 year average)	
	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ug/l) (May-Sept)	Wabasso				27 (10 year average)
	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35