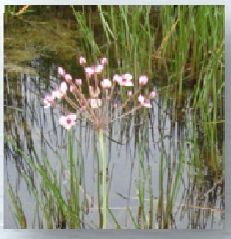
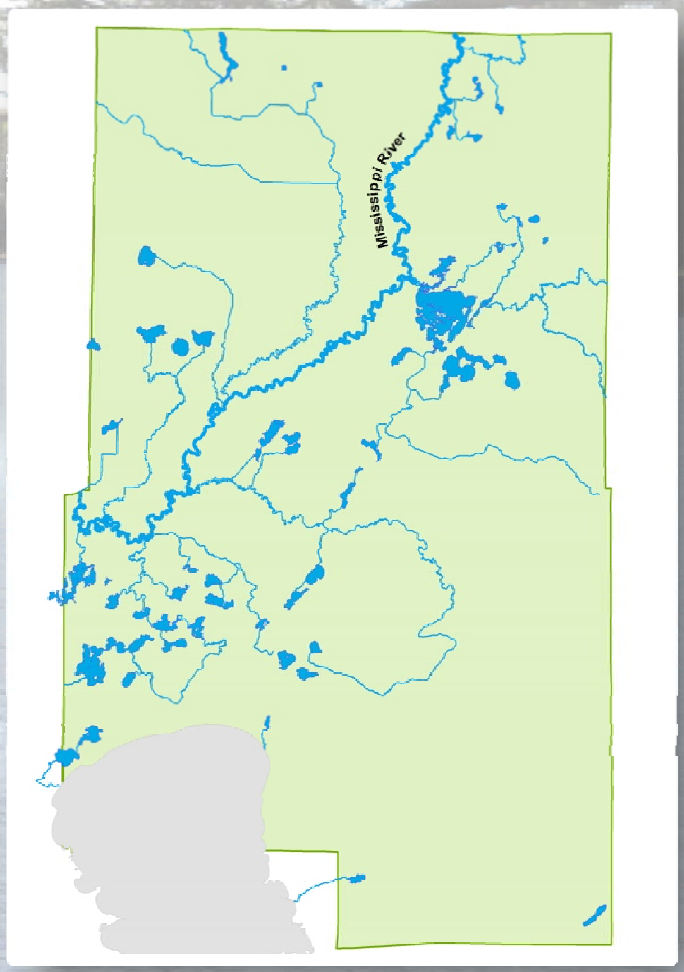
Aitkin County

AIS Prioritization

A planning tool developed for AIS risk management and prevention

2015





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Funded by: Aitkin County Soil & Water Conservation District

Assessment Development: Moriya Rufer
RMB Environmental Laboratories
22796 County Highway 6
Detroit Lakes, MN 56501
218-846-1465
moriyar@rmbel.info
http://rmbel.info

Data Sources: Aitkin County Lake Associations
Aitkin County
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency

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Introduction

Background

Aquatic Invasive Species (AIS) are aquatic plants and animals that are not native to Minnesota, and cause environmental changes to our waters, have negative economic consequences to our communities, or are harmful to human health. Minnesota's natural resources are threatened by a number of Aquatic Invasive Species such as Zebra mussels, Flowering rush, Eurasian watermilfoil and Asian carp. Invasive species are usually spread by humans.

Zebra mussels are particularly harmful because they spread so rapidly and there are currently no effective treatment options. They attach to hard surfaces such as boats, docks, boat lifts, aquatic plants, and water intake pipes, and can clog pipes, cut feet, and damage boats. Zebra mussels have a large economic impact to water treatment facilities, lakeshore owners, lake recreators, and the tourism industry.

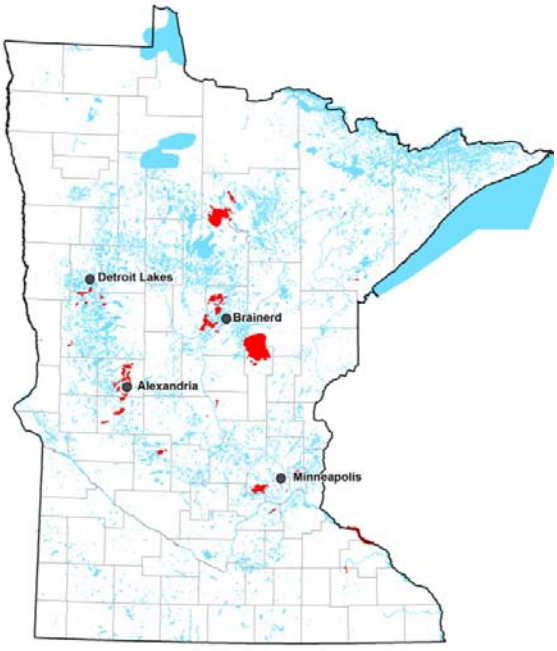


Figure 1. Minnesota Lakes infested by Zebra mussels, 2014.

Zebra mussels also affect the aquatic ecosystem by filtering out microscopic plankton from the water, and therefore removing the food source for other aquatic organisms. This has implications up the food chain, such as affecting fish populations.

As of 2014, approximately 60 lakes in Minnesota are infested with Zebra mussels (MNDNR 2014) (Figure 1). The infestations are clustered around areas with high traffic lakes such as Brainerd, Alexandria, Detroit Lakes and Minneapolis. This pattern of spread is consistent with what has been seen in Michigan, another state with Zebra mussel infested lakes (Johnson *et al.* 2006).

In order to slow or stop the spread of Zebra mussels in Minnesota, a concentrated effort is required. Ideally, unlimited resources would be available to protect all lakes, but in reality budgets are always limited. Therefore, prioritizing lakes due to their risk of infestation is helpful in creating and implementing an AIS management plan.

Project Goals

Highest risk time of year
+
Highest risk lakes
=
When/where to focus AIS prevention

The goals of this project were to assess the risk of Zebra mussel infestation in Aitkin County in order to prioritize funding and efforts to prevent the further spread of Zebra mussels. Sixty lakes were selected by Aitkin County for this prioritization document. Lakes were chosen based on size, public accesses and use.

Vectors of spread were evaluated for each lake such as connectivity to other water bodies and public use. In addition, the suitability of each water body to Zebra mussel establishment was evaluated considering water chemistry, substrate, dissolved oxygen and temperature. A report card was developed for each water body showing the available data and assigned risk category.

These risk ratings can be used in AIS management plans to prioritize lakes for specific prevention measures. A summary table using the assessments to form management recommendations is provided (Table 13). This table can used to guide the most efficient use of AIS funds in the most effective way possible.

Setting

Watersheds

A basin is the area of land drained by a river or lake and its tributaries. Minnesota has 4 divides. All water in Minnesota eventually flows into 1 of 4 rivers. The divides are made of 8 major drainage basins (Figure 2). Each drainage basin is made up of smaller units called watersheds, which correspond to the drainage of a tributary or lake system.

Watersheds are categorized as major or minor. A minor watershed is the smallest category of watershed. A group of minor watersheds that eventually flows into a common stream, such as the Pine River, forms a major watershed. A group of major watersheds that flow into a common river, such as the Mississippi River, form a basin. A group of basins that flow into a common river form a divide.

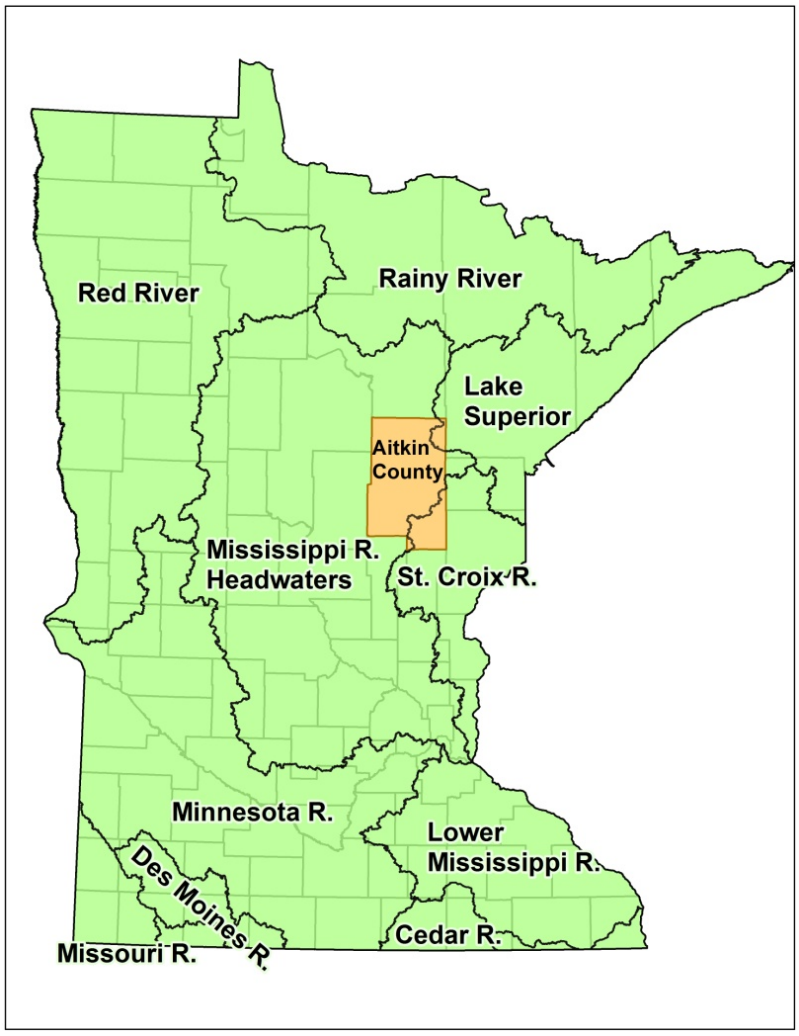


Figure 2. Minnesota showing all major drainage basins and Aitkin County.

The Upper Mississippi River Basin covers approximately 20,100 square miles. It starts at the Headwaters in Itasca State Park and runs a general north easterly course to Bemidji, then over to Grand Rapids before turning south and running through Brainerd, Little Falls, St. Cloud and the Twin Cities Metro area before it combines with the St. Croix River at Lock and Dam 2 near Hastings. As the river runs its course it drains a mixture of forests, prairie, agriculture and urban land areas (MPCA 2000).

Aitkin County

Aitkin County contains seven major watersheds: Mississippi Grand Rapids Watershed, Pine River Watershed, St. Louis River Watershed, Mississippi Brainerd Watershed, Rum River Watershed, Kettle River Watershed and Snake River Watershed (Figure 3). Most of the lakes in the county, however, are located in the Mississippi Grand Rapids and Mississippi Brainerd Major Watersheds. Watersheds are important to consider in aquatic invasive species (AIS) planning because AIS can spread downstream. An infestation in a large chain of lakes, such as along the Mississippi River, can have implications for spread throughout the rest of the Mississippi River Basin.

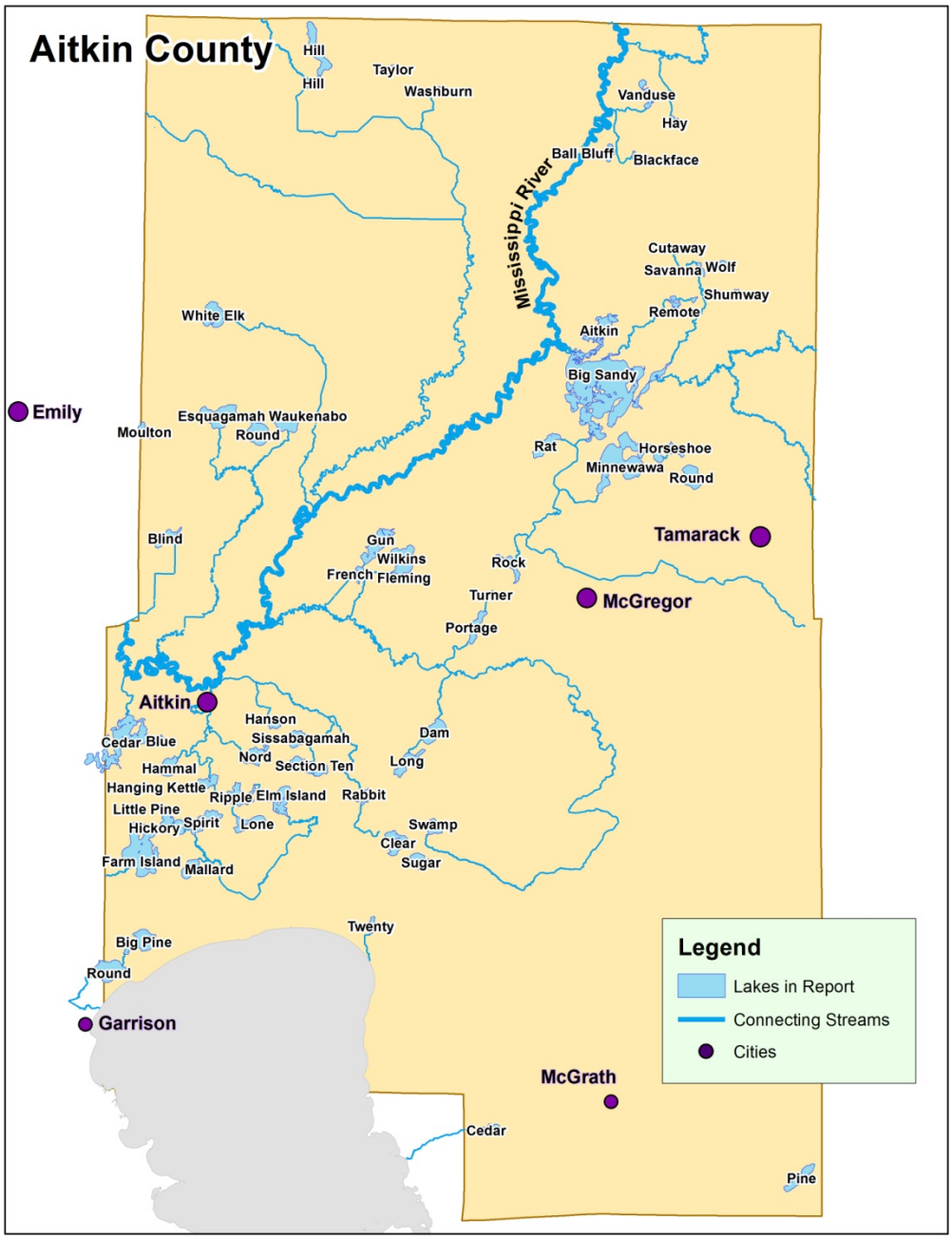


Figure 3. Aitkin County with its lakes and rivers.

History of AIS in Aitkin County

Plants

Curly-leaf pondweed is a common invasive plant in Aitkin County and in Minnesota (Figure 4). It is unknown when it was first established; however, it was most likely introduced to the state by accident in the early 1900s when common carp were intentionally brought to Minnesota. Curly-leaf pondweed has been in Minnesota so long that many people do not realize that it is a non-native species (DNR).

As of March 2015, Curly-leaf pondweed is documented in eight locations in Aitkin County (Figure 5). It is possible that it exists in other lakes as well and is just not documented. Curly-leaf pondweed is able to be controlled with aquatic herbicides.

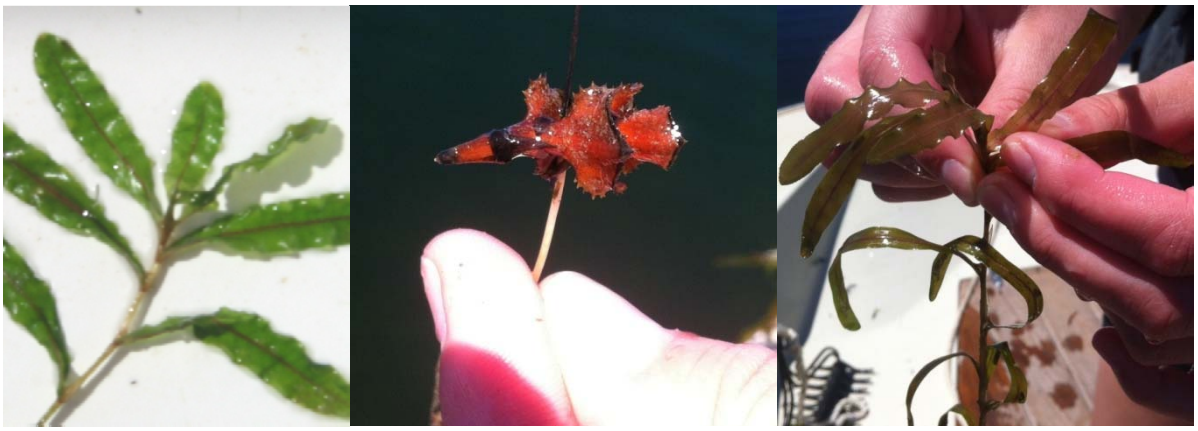


Figure 4. Curly-leaf pondweed (left), turion (wintering bud) (middle), and young Curly-leaf pondweed plant beginning to curl (right).

Zebra mussels

Zebra mussel adults were first documented in Lake Mille Lacs in 2005 (Figure 7). Since 2005, Zebra mussel populations in Mille Lacs grew exponentially until 2013-2014, when they appear to have leveled off. There are no other documented Zebra mussel infestations in Aitkin County as of May 2015, which means that they have not spread out of Mille Lacs in the 10 years that it's been infested.

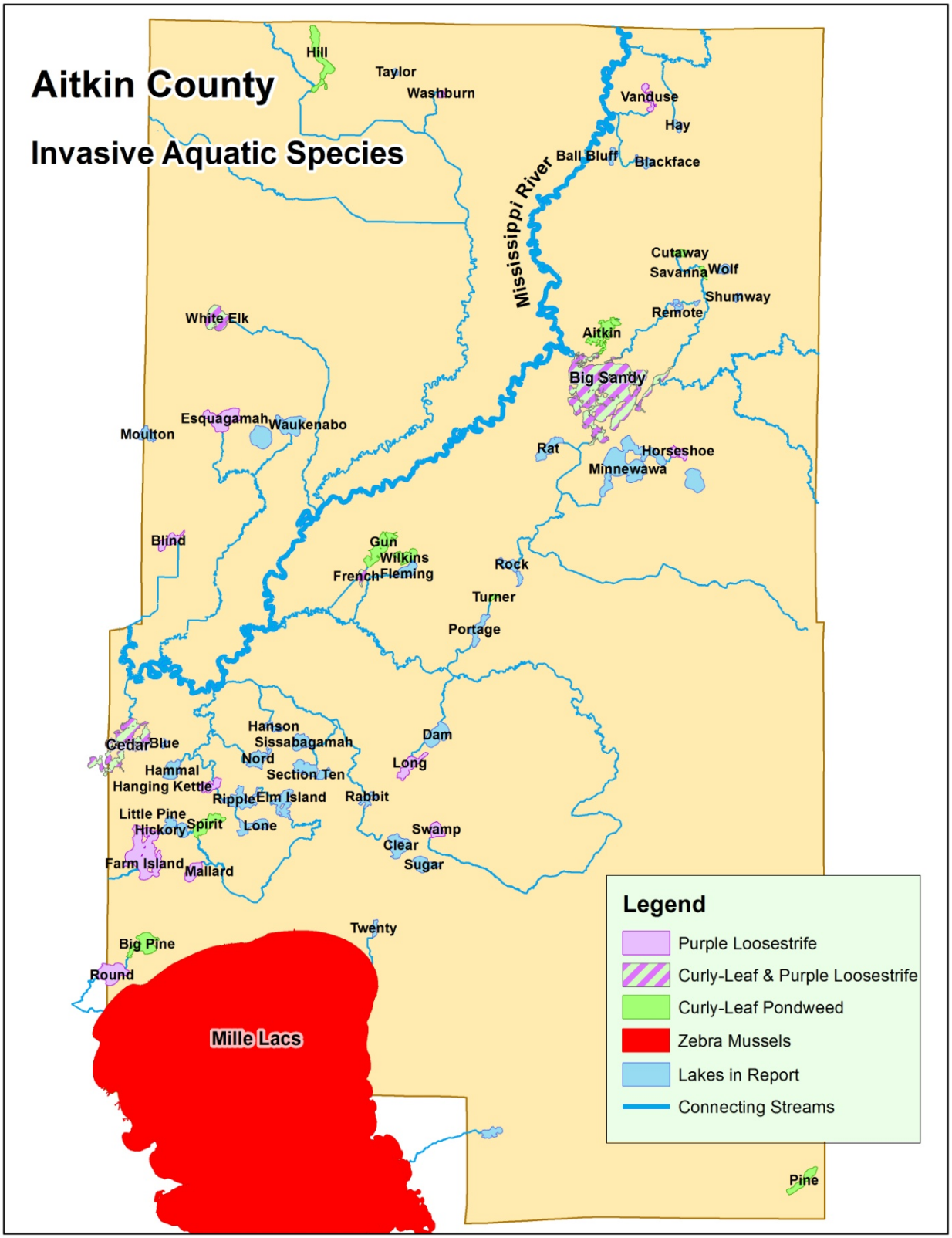


Figure 5. Aquatic species infestations in Aitkin County.

Zebra Mussel Risk Assessment

Lake Methods

The selected lakes in Aitkin County have water chemistry, temperature, and dissolved oxygen data available (Table 1). These data were collected by Aitkin County, Lake Associations, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources and were used in the Zebra mussel risk assessment for lakes.

Table 1. Major lakes in Aitkin County.

Lake Name	Lake ID
Aitkin	01004000
Ball Bluff	01004600
Big Pine (Hazelton)	01015700
Big Sandy	01006200
Blackface	01004500
Blind	01018800
Blue	01018100
Cedar (Aitkin/FI TWPS)	01020900
Cedar(Idun TWP)	01006500
Clear (Glen TWP)	01009300
Cutaway	01005600
Dam	01009600
Elm Island	01012300
Esquagamah	01014700
Farm Island	01015900
Fleming	01010500
French (Fleming TWP)	01010400
Gun	01009900
Hammal	01016100
Hanging Kettle	01017000
Hanson	01013200
Hay	01005900
Hickory	01017900
Hill (Hill Lake TWP)	01014200
Horseshoe (Shamrock)	01003400
Little Pine (Farm Island TWP)	01017600
Lone	01012500
Long (Glen TWP)	01008900
Loon (Townline)	01002400
Mallard	01014900
Minnewawa	01003300
Moulton	01021200
Nord	01011700
Pine (Wagner TWP)	01000100
Portage	01006900
Rabbit	01009100
rat	01007700
remote	01003800
Ripple (Nordland TWP)	01014600
Rock	01007200
Round (Hazelton TWP)	01020400

Lake Name	Lake ID
Round (Shamrock TWP)	01002300
Round (Waukenabo TWP)	01013700
Savanna	01001400
Section 12	01012000
Shumway	01001500
Sissabagamah	01012900
Spirit	01017800
Sugar (Glen/Malmo TWPS)	01008700
Swamp	01009200
Taylor	01010900
Turner	01007400
Twenty	01008500
Vanduse	01005800
Washburn	01011100
Waukenabo	01013600
White Elk	01014800
Wilkins	01010200
Wladimaraf (Section 10)	01011500
Wolf	01001900

Water Connectivity

One of the highest risks to a water body becoming infested with Zebra mussels is if a nearby upstream lake is infested (Horvath 1996). Infested lakes can serve as a source of Zebra mussel veligers for downstream water bodies and adjacent lakes; however the inter-lake distance must be fairly close for the spread to be possible. Various studies have suggested a downstream veliger dispersal of 1-18 km (0.6-11 miles) in small streams (Lucy *et al.* 2005; Horvath *et al.*1996). In this assessment, lakes that have an infested lake already identified less than 20 km (12 mi) upstream are at a high risk of infestation since the Zebra mussels could spread downstream (Table 2). Lakes that are in a chain have a moderate risk because if any upstream lakes get infested with Zebra mussels (<20 km), they could spread downstream. Headwaters lakes have a very low risk of infestation through water connectivity.

In addition to stream connections, adjacent water bodies have the potential to infest each other via boats going from one lake to another, regardless if the lakes are connected or not.

Table 2. Water connectivity and the related risk of Zebra mussel infestation.

Water Connectivity Category	Risk of infestation
Headwaters lake	Low risk
Chain of lakes	Moderate risk
Upstream infested lake	High risk

Public Use

Boats and water related equipment have been shown to be one of the largest vectors in the spread of Zebra mussels (Johnson *et al.* 2001). Public use can be measured by some surrogate statistics. First, the number of public accesses and related parking spots are known on each lake. The more public accesses on the lake, the more potential boats can use the lake. Secondly, the number of resorts and hotels on the lake are documented through The Aitkin Area Chamber of Commerce. The hotels and resorts on the lake attract local and regional visitors, increasing the risk of infestation. Thirdly, the number of fishing tournaments and special events on lakes is documented through a permitting process. Fishing tournaments and special events draw visitors to the lakes. And finally, the homeowners on the lake own an average of one dock/boat lift/boat per property. The purchase of an infested boat lift or other water related equipment has been the source of several documented new infestations in Minnesota. This use

relationship coupled with transport of boats and water equipment from lake to lake, increases the probability of infestation. "Destination lakes" for popular fish species like walleyes and muskies along with popular recreation waters for boating and swimming are at increased risk for infestation.

Public access inspections data was reviewed for each lake, but difficulty in standardizing data across lakes challenges the reliability of these data to be used as part of public use data for the final risk assessment.

The numbers used represent boating units per summer. For parcels, an average of one boat per parcel was used in the calculation. For fishing tournaments, the total boats participating in the tournament was used.

For access parking and resort units, the numbers were multiplied by 15 weeks of summer between Memorial Day and Labor Day for an estimated total summer use. This number is likely underestimated, but the ratings still come out the same either way, showing that the calculations are very robust (Tables 3-4). In weighting the resorts and accesses by the 15 weeks of summer, they are weighted appropriately compared to the resident parcels.

Table 3. Public use rating calculations.

Lake	Parcels*	Access Parking*	Resort Units*	Fishing Tournaments*	Total*	Risk
Big Sandy	1,547	525	300	75	2,447	High
Minnewawa	707	360	90	75	1,232	High
Farm Island	464	375	150	0	989	Moderate
Cedar (Aitkin/Fi Twps)	402	210	150	0	762	Moderate
Hickory	44	30	450	0	524	Moderate
Spirit	180	180	135	0	495	Moderate
Hill (Hill Lake Twp)	245	210	0	0	455	Moderate
Pine (Wagner Twp)	223	180	0	0	403	Low
Big Pine (Hazelton)	228	150	0	0	378	Low
Lone	215	150	0	0	365	Low
Round (Shamrock Twp)	190	150	0	0	340	Low
Round (Waukenabo Twp)	167	120	0	0	287	Low
Sissabahgama	42	240	0	0	282	Low
Long (Glen Twp)	205	75	0	0	280	Low
Esquahgama	204	75	0	0	279	Low
Gun	198	75	0	0	273	Low
Ripple (Nordland Twp)	122	135	0	0	257	Low
Round (Hazelton Twp)	137	120	0	0	257	Low
Elm Island	165	90	0	0	255	Low
Waukenabo	132	120	0	0	252	Low
Clear (Glen Twp)	143	105	0	0	248	Low
Nord	111	135	0	0	246	Low
Wilkins	139	105	0	0	244	Low
Sugar (Glen/Malmo Twps)	119	120	0	0	239	Low
Section 12 LAKE	81	150	0	0	231	Low
Fleming	119	90	0	0	209	Low

Lake	Parcels*	Access Parking*	Resort Units*	Fishing Tournaments*	Total*	Risk
Hanging Kettle	114	90	0	0	204	Low
Dam	111	90	0	0	201	Low
Aitkin	38	75	75	0	188	Low
Little Pine (Farm Island Twp)	66	120	0	0	186	Low
Wladimaraf (section 10 Lake)	47	135	0	0	182	Low
Rock	78	90	0	0	168	Low
Vanduse	96	60	0	0	156	Low
Rabbit	94	60	0	0	154	Low
Hammal	75	60	0	0	135	Low
Blind	50	75	0	0	125	Low
Horseshoe (Shamrock)	94	30	0	0	124	Low
Hanson	16	90	0	0	106	Low
Portage	76	30	0	0	106	Low
Ball Bluff	44	60	0	0	104	Low
Remote	8	90	0	0	98	Low
Hay	20	75	0	0	95	Low
Mallard	15	75	0	0	90	Low
White Elk	15	75	0	0	90	Low
Swamp	11	75	0	0	86	Low
Blue	21	60	0	0	81	Low
French (Fleming Twp)	44	30	0	0	74	Low
Turner	14	60	0	0	74	Low
Cutaway	11	60	0	0	71	Low
Moulton	10	60	0	0	70	Low
Twenty	10	60	0	0	70	Low
Taylor	37	30	0	0	67	Low
Blackface	21	45	0	0	66	Low
Cedar (Idun Twp)	66	0	0	0	66	Low
Loon (Townline)	6	60	0	0	66	Low
Rat	38	15	0	0	53	Low
Savanna	11	30	0	0	41	Low
Shumway	7	30	0	0	37	Low
Washburn	5	30	0	0	35	Low
Wolf	9	0	0	0	9	Low

**All numbers are the total number of boats for the 15 weeks of summer.*

Table 4. Use ratings and assigned risk for Zebra mussel infestation.

	Low Risk	Moderate Risk	High Risk
Total Boat Units (the sum of public access parking spaces, resort units, lake parcels and special events)	0-425	476-1,000	1,000+

Water Chemistry

Available water quality data was compiled and analyzed for each major lake in Aitkin County. The average was calculated for each available parameter. The values were then compared to the ranges in Table 5 to determine the potential for Zebra mussels to establish and reproduce in the water body. Calcium was considered first, based on its importance in shell formation (Mackie & Schloesser 1996); however calcium data were not available for all water bodies. Next, alkalinity, hardness and pH were considered (Mackie & Claudi 2010; Hincks & Mackie 1997). Lastly, Secchi depth, chlorophyll a and total phosphorus were considered, although they are not sufficient parameters alone to assess risk (Mackie & Claudi 2010).

Total phosphorus and chlorophyll a are useful or determining the lake's trophic state, which does affect suitability for Zebra mussels. Zebra mussels thrive best in mesotrophic lakes (Karatayev et al. 1998, Nelepa 1992). Eutrophic lakes have a lower suitability due to too much phosphorus and chlorophyll a, and usually softer substrates.

Table 5. Water column Zebra mussel suitability criteria (Mackie and Claudi 2010).

	Risk		
Parameter	**Low Little Potential for Larval Development**	**Moderate (survivable, but will not flourish)**	**High (favorable for optimal growth)**
Calcium (mg/l)	8-15	15-30	>30
pH	7.0-7.8 or 9.0-9.5	7.8-8.2 or 8.8-9.0	8.2-8.8
Hardness (mg/L)	30-35	55-100	100-280
Alkalinity (mg/L)	30-55	55-100	100-280
Specific Conductance (umhos)	30-60	60-110	>110
Secchi depth (m)	1-2 or 6-8	4-6	2-4
Chlorophyll a (ug/L)	2.0-2.5 or 20-25	8-20	2.5-8
Total Phosphorus	5-10 or 35-50	10-25	25-35

Substrate Suitability

One of the reasons Zebra mussels are such a nuisance is that they attach to hard substrates via their byssal threads. Zebra mussels prefer a hard substrate for attachment although they will attach to plants as well (Karatayev et al. 1998). In lakes, they have been documented to colonize on rocks, docks, boatlifts and water intake pipes. Lakes with mainly soft substrate and not many man-made structures may not be as supportive to Zebra mussel colonization. Plants have just moderate suitability because in Minnesota they die off at the end of each summer, meaning the Zebra mussels that are attached to them must crawl to other substrates or die off during winter (Karatayev et al. 1998). Comments are made for each water body, its dominant substrate, and its likelihood to support Zebra mussels. The substrate types were determined by the MNDNR (Table 6).

Table 6. Substrate descriptions and their suitability to Zebra mussel survival.

Substrate (MNDNR)	**Description**	**Suitability to Zebra mussels**
Muck	Decomposed organic material	Low
Marl	Calcareous material	Low
Silt	Fine material with little grittiness	Low
Sand	Diameter less than 1/8 inch	Low
Submerged macrophytes	Underwater rooted plants	Moderate
Gravel	Diameter 1/8 to 3 inches	High
Rubble	Diameter 3 to 10 inches	High
Boulder	Diameter over 10 inches	High

Temperature

Zebra mussels begin reproduction when water temperature is above 12 C, but ideal reproduction temperature occurs above 17-18 C (McMahon 1996). The upper thermal limit for North American Zebra mussels occurs somewhere around 30 C (McMahon 1996) The optimal temperature range for zebra mussel spawning in North America is estimated to between 18-26 C.

In Minnesota, lakes are usually ice-covered on average from November to March. During the ice-covered season, it is assumed that the water temperature is too cold for Zebra mussel spawning. However, the Zebra mussels do over-winter at the bottom of the lake (Mackie *et al.* 1989).

In summer, Minnesota lakes rarely exceed 30 C (86 F); therefore, it is likely that the Zebra mussels reproduce all summer once the water temperature reaches 17-18 C. This occurrence has been documented in Pelican Lake, where Zebra mussel veligers were first found at 18 C in 2012 and 19 C in 2013 (Rufer 2015).

The maximum temperature was reported for each lake and the risk was assigned based on if the lake exceeded 32 C in mid-summer or not (Table 7). The lake's mixing regime and period of hypolimnetic anoxia were also noted as research has found that few Zebra mussel veligers occur below the thermocline in temperate lakes (Mackie *et al.* 1989).

Table 7. Temperature values and their impact on Zebra mussel survival.

Survival Potential	Temperature Range	Risk Rating
Prevent zebra mussel establishment	> 32 C	Low
Little impact on mussel survival	8 – 31 C	High

Infestation Risk Rating

The two main vectors of spread for Zebra mussels are lake connectivity and public use. The risks from these two categories were combined for an overall risk of infestation rating for each lake. A scoring system was used to weight each of these two categories, which resulted in three overall risk categories (Table 8).

Table 8. Combined infestation risk rating using public use and connectivity.

	Public Use Total Boat Units	Connectivity	Combined Risk Rating
Low Risk	0-700	0 = Headwaters Lake	0-1,000
Moderate Risk	701-2,000	2,500 = Chain of Lakes	1,000-6,000
High Risk	2,000+	5,000 = Infested or Infested lake upstream	6,000+

Zebra mussel Suitability Rating

The two main factors for zebra mussels thriving in a lake are suitable water chemistry and suitable substrate. The risks from these two categories were combined for an overall suitability rating for each lake. This suitability rating can be interpreted as the probability that Zebra mussels will thrive in the lake. A scoring system was used to weight each of these two categories, which resulted in three overall risk categories (Table 9).

Table 9. Combined Zebra mussel suitability rating using water chemistry and substrate.

	Water Quality	Substrate	Combined Risk Rating
Low Risk	0 = The majority of averages in green category.	0 = Sand, Silt, Muck	0 - Low
Moderate Risk	500 = The majority of averages in yellow category.	500=Submerged macrophytes	1000 - Moderate
High Risk	1,000 = The majority of averages in red category.	1,000 = Rocks, Gravel, Rubble	2000 - High

River Science

Unlike lakes, rivers are not usually ideal habitat for Zebra mussels. Studies have shown that the turbulence in streams and rivers causes high Zebra mussel veliger mortality and assists in preventing the veligers from settling on hard substrates (Horvath & Lamberti 1999). Without an infested lake upstream continually supplying the stream with Zebra mussel veligers, the stream is unlikely to sustain a large population on its own. Although streams can be pathways for downstream infestations, the probability of Zebra mussel veliger survival decreases with distance downstream (Horvath & Lamberti 1999; Horvath *et al.* 1996).

For small streams, even the presence of an infested lake upstream supplying veligers will probably not allow the stream to support populations of Zebra mussel adults. Strayer (1991) found that in streams <10 meters wide (33 feet) there were no stable adult Zebra mussel populations. Zebra mussel adults seem to only survive in the largest rivers (>100 m wide) or large pools and stagnant backwaters.

Turbulence & Flow
Studies show that turbulence or shear may be the limiting factor for Zebra mussel survival in streams and rivers (Horvath & Lamberti 1999). Although specific flow rates are not determined, it appears that in streams and rivers, zebra mussels are only self-sustaining behind dams and stagnant backwaters. Therefore, for the purposes of this risk assessment, any stream sites are considered to have low risk due to the flow in the river, even if there is no flow data available.

Downstream Dispersal
Zebra mussel veliger abundance has been shown to decrease with distance in streams. Veligers have been found 10-18 km (6-11 miles) downstream of an infested lake in stream systems (Horvath *et al*.,1996). In heavily vegetated wetland stream systems, the dispersal distance has been found to be about 1 km (0.6 mile), which is much lower. There are a few possible factors affecting Zebra mussel veliger survival in wetlands streams, including aquatic vegetation, low water velocity, unsuitable water characteristics, limited substrate availability, and/or increased predation pressure (Bodamer & Brossenbroek 2008). These results show that protecting aquatic vegetation from removal, limiting stream dredging, and installing wetlands could help as a barrier for spreading Zebra mussels downstream.

The small streams in Aitkin County have some submerged vegetation, usually lined with emergent vegetation, has sandy/rocky substrate and mostly clear water. Taking into account the literature and the condition and habitat of the river, for the purposes of this risk assessment, 32 km (20 mi) is considered the longest a veliger could theoretically travel. This distance of 32 km is very conservative, but until further research is conducted a better estimate is not available.

Water Quality

The water chemistry ranges from Mackie and Claudi 2010 (Table 5) can be applied to streams; however, more applicable water quality parameters to streams are turbidity and total suspended solids. Turbidity has been shown to limit Zebra mussel survival. Although acute exposures to high turbidity can negatively affect a Zebra mussel population, they are able to compensate for some high exposure (McMahon 1996). Chronic high turbidity has a greater negative effect on Zebra mussel survival, as it inhibits their filtering ability (McMahon 1996, Karatayev *et al.* 1998). Mackie and Claudi (2010) suggest upper limits for Zebra mussel survival for total suspended solids at 96 mg/L and turbidity at 80 NTU, if the turbidity is caused mainly from sediment suspension. The combination of high temperature and high turbidity seem to be most stressful to Zebra mussels (Alexander 1994).

Lake Risk Assessment Summary: Aitkin Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: NA
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of McGregor
Surface Area: 487 acres
Percent Littoral: 90%
Max Depth: 35 feet
Inlet: Streams from Bass Lake, Tiesen Lake, and a headwaters stream

Summary

Aitkin Lake has low public use and two upstream lakes, resulting in a low infestation risk rating. There is no water quality data available for Aitkin Lake, so water chemistry suitability is not able to be evaluated, but the substrate is mainly soft and not ideal for Zebra mussels.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	2 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (38)	188	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (150)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Silt	40.0, 27.2, 7.2	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Ball Bluff Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: High Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: West of Floodwood
Surface Area: 159 acres
Percent Littoral: 43.33%
Max Depth: 75.9 feet
Inlet: None

Summary

Ball Bluff Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Ball Bluff Lake, they would likely thrive due to suitable water chemistry, although they could be limited somewhat by substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (44)	104	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Silt, Marl	45.0, 23.0, 20.0, 10.8	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	82	1	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	120	5	100-280
Specific Conductance *	uS/cm	NA	0	>110
Secchi Depth	ft	14.2	5	6.56-13.12
Chlorophyll a	ug/L	4.14	5	2.5-8
Total Phosphorus	ug/L	6	5	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Big Pine Lake (Hazelton)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Rum R.
Location: North of Garrison
Surface Area: 635 acres
Percent Littoral: 54.67%
Max Depth: 78 feet
Inlet: headwater streams

Summary

Big Pine Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Big Pine Lake they would likely thrive due to suitable water chemistry and substrate (rubble and gravel).

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream Lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (228)	378	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (150)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Silt, Rubble, Gravel	48.9, 30.6, 28.3, 25.6, 22.8	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA		>30
pH*		8.3	58	8.2-8.8
Alkalinity*	mg/L	97.2	5	100-280
Specific Conductance *	uS/cm	248.2	56	>110
Secchi Depth	ft	12.1	268	6.56-13.12
Chlorophyll a	ug/L	4.0	5	2.5-8
Total Phosphorus	ug/L	15.2	5	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	30 (286)	>32 C	High
Dissolved oxygen	10.7 (6)	<7 mg/L	High

Lake Risk Assessment Summary: Big Sandy Lake

Infestation Risk Rating: High

1. Connectivity: Moderate Risk
2. Public Use: High Risk

Suitability Risk Rating:

1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics

Major Watershed: Mississippi R. -Grand Rapids
Location: North of McGregor
Surface Area: 6,439 acres
Percent Littoral: 30.3%
Max Depth: 80 feet
Inlet: Aitkin Lake, Sandy River Lake, Stream from Remote Lake and Glacier Lake, West Savanna River, Prairie River, Headwater Stream

Summary

Big Sandy Lake has high public use and 33 upstream lakes, which results in a high infestation risk rating. If Zebra mussels were introduced into Big Sandy Lake they would do moderately well due to low pH and alkalinity and high phosphorus.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	33 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (1547)	2,447	High
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (900)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Rubble	81.3, 25.3, 24.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.4	125	8.2-8.8
Alkalinity*	mg/L	54.5	4	100-280
Specific Conductance*	uS/cm	112.6	149	>110
Secchi Depth	ft	4.25	719	6.56-13.12
Chlorophyll a	ug/L	11.4	114	2.5-8
Total Phosphorus	ug/L	40.2	145	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	23.81 (836)	>32 C	High
Dissolved oxygen	8.55 (53)	<7 mg/L	High

Lake Risk Assessment Summary: Blackface Lake

Infestation Risk Rating: Low

1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA

1. Water Chemistry: NA
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: West of Floodwood
Surface Area: 191.8 acres
Percent Littoral: 99.73%
Max Depth: 17.7 feet
Inlet: headwater streams

Summary

Blackface Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There are no water chemistry or substrate data (except for Secchi depth) available for Blackface Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (21)	66	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (45)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	7.13	54	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

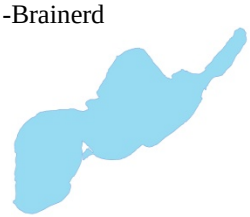
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	
Dissolved oxygen	NA	<7 mg/L	

Lake Risk Assessment Summary: Blind Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Emily
Surface Area: 321 acres
Percent Littoral: 98.95%
Max Depth: 17 feet
Inlet: stream from Coon Lake



Summary

Blind Lake has low public use and 3 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Blind Lake they would likely do moderately well due to soft substrates, low alkalinity and high phosphorus and chlorophyll a.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	3 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (50)	125	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Detritus	46.7, 41.7, 15	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.0	10	8.2-8.8
Alkalinity*	mg/L	77.8	4	100-280
Specific Conductance*	uS/cm	146	10	>110
Secchi Depth	ft	4.78	65	6.56-13.12
Chlorophyll a	ug/L	14	28	2.5-8
Total Phosphorus	ug/L	37.5	29	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27 (64)	>32 C	High
Dissolved oxygen	9.39 (9)	<7 mg/L	High

Lake Risk Assessment Summary: Blue Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA
1. Water Chemistry: NA
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Brai
Location: East of Cuyuna
Surface Area: 53.53 acres
Percent Littoral: 14%
Max Depth: 106 feet
Inlet: None

Summary

Blue Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There are no water chemistry or substrate data available for Blue Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (21)	81	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Cedar Lake (Aitkin/FI TWPS)

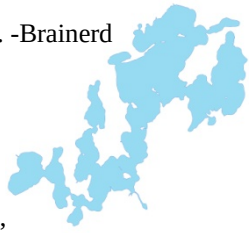
Infestation Risk Rating: High

1. Connectivity: Moderate Risk
2. Public Use: Moderate Risk

Suitability Risk Rating:

1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics 0209
Major Watershed: Mississippi R. -Brainerd
Location: East of Cuyuna
Surface Area: 1,769 acres
Percent Littoral: 23.2%
Max Depth: 105 feet
Inlet: Cedar Brook, streams from Dogfish Lake, Taylor Lake, Brennen Lake, and Ringhand Lake



Summary

Cedar Lake has moderate public use and 13 upstream lakes, resulting in a high infestation risk rating. If Zebra mussels were introduced into Cedar Lake they would likely thrive due to suitable water chemistry and substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	13 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (402)	762	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (360)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Marl, Gravel, Rubble	30.7, 26.7, 19.0, 16.7, 6.7	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	19	8.2-8.8
Alkalinity*	mg/L	105.5	11	100-280
Specific Conductance*	uS/cm	191.6	14	>110
Secchi Depth	ft	10.8	960	6.56-13.12
Chlorophyll a	ug/L	7.8	13	2.5-8
Total Phosphorus	ug/L	16.7	14	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	23 (169)	>32 C	High
Dissolved oxygen	9.81 (9)	<7 mg/L	High

Lake Risk Assessment Summary: Cedar Lake (Idun TWP)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: NA
2. Substrate: Low

Characteristics 0065
Major Watershed: Rum R.
Location: East of Mille Lacs Lake
Surface Area: 232 acres
Percent Littoral: 55.55%
Max Depth: 18 feet
Inlet: None

Summary

Cedar Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There are no water quality data available for Cedar Lake, so water chemistry suitability is not able to be evaluated, but the substrate is mainly soft and not ideal for Zebra mussels.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (66)	66	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (0)		
Substrate Suitability (mean abundance, DNR)		Muck, Detritus, Sand, Silt	45.0, 45.0, 36.7, 13.3	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	
Dissolved oxygen	NA	<7 mg/L	

Lake Risk Assessment Summary: Clear Lake (Glen TWP)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics 0093
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 568 acres
Percent Littoral: 64.26%
Max Depth: 24 feet
Inlet: None

Summary

Clear Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Clear Lake, they would likely do moderately well. The substrate is suitable, but it is possible that Zebra mussels could be somewhat limited by water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (143)	248	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (105)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt, Gravel, Rubble	45.0, 28.3, 25.6, 21.7	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA		>30
pH*		8.1	18	8.2-8.8
Alkalinity*	mg/L	55	3	100-280
Specific Conductance*	uS/cm	172.5	6	>110
Secchi Depth	ft	16.6	269	6.56-13.12
Chlorophyll a	ug/L	1.9	14	2.5-8
Total Phosphorus	ug/L	15.7	14	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	30 (94)	>32 C	High
Dissolved oxygen	11.48 (2)	<7 mg/L	High

Lake Risk Assessment Summary: Cutaway Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA
1. Water Chemistry: NA
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of Tamarack
Surface Area: 112.73 acres
Percent Littoral: 64.11%
Max Depth: 23.9 feet
Inlet: Stream from Rat House Lake

Summary

Cutaway Lake has low public use and 4 upstream lakes, resulting in a low infestation risk rating. There are no water chemistry or substrate data available for Cutaway Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	4 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (11)	71	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

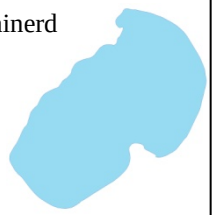
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	
Dissolved oxygen	NA	<7 mg/L	

Lake Risk Assessment Summary: Dam Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: East of Aitkin
Surface Area: 598 acres
Percent Littoral: 37.31%
Max Depth: 47.7 feet
Inlet: Stream from Lily Lake



Summary

Dam Lake has low public use and 3 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Dam Lake, they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	3 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (111)	201	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Boulder	83.3, 38.9, 16.1	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	39	8.2-8.8
Alkalinity*	mg/L	74.5	4	100-280
Specific Conductance*	uS/cm	215	9	>110
Secchi Depth	ft	10.0	263	6.56-13.12
Chlorophyll a	ug/L	9.8	28	2.5-8
Total Phosphorus	ug/L	21.8	28	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27.61 (239)	>32 C	High
Dissolved oxygen	10.29 (4)	<7 mg/L	High

Lake Risk Assessment Summary: Elm Island Lake

Infestation Risk Rating: Moderate
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 518 acres
Percent Littoral: 75.24%
Max Depth: 25 feet
Inlet: Ripple River

Summary

Elm Island Lake has low public use, but 20 upstream lakes, resulting in a moderate infestation risk rating. If Zebra mussels were introduced into Elm Island Lake they would likely only do moderately well due to high chlorophyll a and phosphorus and soft substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	20 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (165)	255	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Gravel	51.8, 38.7, 11.9	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA		>30
pH*		7.9	34	8.2-8.8
Alkalinity*	mg/L	73.8	8	100-280
Specific Conductance*	uS/cm	218.8	9	>110
Secchi Depth	ft	3.63	347	6.56-13.12
Chlorophyll a	ug/L	21.7	27	2.5-8
Total Phosphorus	ug/L	59.9	25	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27 (137)	>32 C	High
Dissolved oxygen	9.51 (11)	<7 mg/L	High

Lake Risk Assessment Summary: Esquagamah Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: East of Emily
Surface Area: 837 acres
Percent Littoral: 61.79%
Max Depth: 30.9 feet
Inlet: 4 headwater streams

Summary

Esquagamah Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Esquagamah Lake they would likely do moderately well due to high chlorophyll a and phosphorus. The substrate is suitable for Zebra mussels.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (204)	279	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		Sand, Boulder, Rubble	79.4, 17.2, 11.7	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA		>30
pH*		7.9	54	8.2-8.8
Alkalinity*	mg/L	73.8	7	100-280
Specific Conductance*	uS/cm	170.4	15	>110
Secchi Depth	ft	4.3	416	6.56-13.12
Chlorophyll a	ug/L	17.8	36	2.5-8
Total Phosphorus	ug/L	47.3	36	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27.9 (190)	>32 C	High
Dissolved oxygen	10.77 (11)	<7 mg/L	High

Lake Risk Assessment Summary: Farm Island Lake

Infestation Risk Rating: High
1. Connectivity: Moderate Risk
2. Public Use: Moderate Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainer
Location: South of Aitkin
Surface Area: 2,003 acres
Percent Littoral: 52.68%
Max Depth: 51.3 feet
Inlet: Ripple River, stream from Horseshoe Lake

Summary

Farm Island Lake has moderate public use and ten upstream lakes, resulting in a high infestation risk rating. In addition, when Lake Mille Lacs (infested with Zebra mussels) is too windy, fishermen move onto Farm Island Lake, adding risk. If Zebra mussels were introduced into Farm Island Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	10 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (464)	989	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (525)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Gravel, Rubble	70.8, 18.8, 13.3, 8.3	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.0	12	8.2-8.8
Alkalinity*	mg/L	82.7	3	100-280
Specific Conductance*	uS/cm	220.7	12	>110
Secchi Depth	ft	11.5	541	6.56-13.12
Chlorophyll a	ug/L	5.4	34	2.5-8
Total Phosphorus	ug/L	20.1	38	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 (258)	>32 C	High
Dissolved oxygen	11.88 (4)	<7 mg/L	High

Lake Risk Assessment Summary: Fleming Lake

Infestation Risk Rating: Low

1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate

1. Water Chemistry: Moderate Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 314 acres
Percent Littoral: 33.5%
Max Depth: 15 feet
Inlet: stream from Wilkins Lake

Summary

Fleming Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Fleming Lake, they would likely only do moderately well due to high chlorophyll a and phosphorus and soft substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (119)	209	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Sand, Clay, Silt, Detritus	55.8, 21.7, 16.7, 10.0	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	11	8.2-8.8
Alkalinity*	mg/L	57.3	8	100-280
Specific Conductance*	uS/cm	120	15	>110
Secchi Depth	ft	3.8	282	6.56-13.12
Chlorophyll a	ug/L	35.7	44	2.5-8
Total Phosphorus	ug/L	60.2	48	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.82 (79)	>32 C	High
Dissolved oxygen	9.25 (13)	<7 mg/L	High

Lake Risk Assessment Summary: French Lake (Fleming TWP)

Infestation Risk Rating: Moderate
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 137 acres
Percent Littoral: 51.56%
Max Depth: 44 feet
Inlet: Stream from Gun Lake

Summary

French Lake has low public use and two upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into French Lake they would likely thrive due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	2 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (44)	74	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	1	8.2-8.8
Alkalinity*	mg/L	120	1	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	6.5	17	6.56-13.12
Chlorophyll a	ug/L	7.7	9	2.5-8
Total Phosphorus	ug/L	26.1	10	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	19.5 (9)	>32 C	High
Dissolved oxygen	7.47 (9)	<7 mg/L	High

Lake Risk Assessment Summary: Gun Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 717 acres
Percent Littoral: 40.73%
Max Depth: 44 feet
Inlet: Stream from Jenkin's Lake

Summary

Gun Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Gun Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (198)	273	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Gravel, Detritus, Rubble	51.7, 37.9, 24.7, 22.4, 7.4	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	39	8.2-8.8
Alkalinity*	mg/L	107.8	16	100-280
Specific Conductance*	uS/cm	201.7	36	>110
Secchi Depth	ft	6.2	142	6.56-13.12
Chlorophyll a	ug/L	9.5	36	2.5-8
Total Phosphorus	ug/L	31.2	46	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.08 (176)	>32 C	High
Dissolved oxygen	8.88 (18)	<7 mg/L	High

Lake Risk Assessment Summary: Hammal Lake

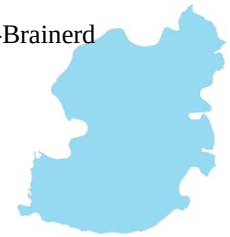
Infestation Risk Rating: Low

1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate

1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 376 acres
Percent Littoral: 69.69%
Max Depth: 44 feet
Inlet: None



Summary

Hammal Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Hammal Lake they would likely do moderately well due to low alkalinity, pH and specific conductance. Testing the calcium for Hammal Lake would allow for better suitability risk assessment.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (75)	135	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt, Muck, Gravel, Rubble	44.2, 40.0, 31.7, 10.0, 9.2	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.9	38	8.2-8.8
Alkalinity*	mg/L	40.0	3	100-280
Specific Conductance*	uS/cm	78	9	>110
Secchi Depth	ft	11.0	48	6.56-13.12
Chlorophyll a	ug/L	4.4	17	2.5-8
Total Phosphorus	ug/L	17.1	19	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.5 (138)	>32 C	High
Dissolved oxygen	8.52 (9)	<7 mg/L	High

Lake Risk Assessment Summary: Hanging Kettle Lake

Infestation Risk Rating: Moderate

1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate

1. Water Chemistry: High Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 302 acres
Percent Littoral: 44.85%
Max Depth: 35 feet
Inlet: Ripple River, stream from Bachelor Lake

Summary

Hanging Kettle Lake has low public use and 26 upstream lakes, resulting in a moderate infestation risk rating. If Zebra mussels were introduced into Hanging Kettle Lake they would likely do moderately well due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	26 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (114)	204	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Gravel	56.7, 40.8, 18.3	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.9	20	8.2-8.8
Alkalinity*	mg/L	76.8	4	100-280
Specific Conductance*	uS/cm	206.3	7	>110
Secchi Depth	ft	6.9	19	6.56-13.12
Chlorophyll a	ug/L	12.3	14	2.5-8
Total Phosphorus	ug/L	30.2	15	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28.5 (89)	>32 C	High
Dissolved oxygen	11.01 (2)	<7 mg/L	High

Lake Risk Assessment Summary: Hanson Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: NA
2. Substrate: Low

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 143.28 acres
Percent Littoral: 61.41 %
Max Depth: 42 feet
Inlet: 2 headwater streams

Summary

Hanson Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There is no water quality data available for Hanson Lake, so water chemistry suitability is not able to be evaluated, but the substrate is mainly soft and not ideal for Zebra mussels.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (16)	106	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Muck	75.0	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Hay Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: High Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: West of Floodwood
Surface Area: 128.88 acres
Percent Littoral: 44.23 %
Max Depth: 32 feet
Inlet: None

Summary

Hay Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Hay Lake they would likely thrive due to suitable water chemistry, although they could be limited somewhat by substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (20)	95	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Silt	35.0, 31.7, 20.0	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	1	8.2-8.8
Alkalinity*	mg/L	96	1	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	6.6	1	6.56-13.12
Chlorophyll a	ug/L	6.2	1	2.5-8
Total Phosphorus	ug/L	9.0	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	19.5 (9)	>32 C	High
Dissolved oxygen	10.8 (1)	<7 mg/L	High

Lake Risk Assessment Summary: Hickory Lake

Infestation Risk Rating: High
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Braine
Location: South of Aitkin
Surface Area: 197 acres
Percent Littoral: 52.46 %
Max Depth: 32 feet
Inlet: Ripple River

Summary

Hickory Lake has moderate public use and 12 upstream lakes, resulting in a high infestation risk rating. If Zebra mussels were introduced to Hickory Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	12 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (44)	524	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (480)		
Substrate Suitability (mean abundance, DNR)		Detritus, Muck, Gravel, Rubble	40.0, 35.0, 10.0, 10.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	11.5	10	6.56-13.12
Chlorophyll a	ug/L	2.7	11	2.5-8
Total Phosphorus	ug/L	13.5	11	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Hill Lake (Hill Lake TWP)

Infestation Risk Rating: Moderate
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of Hill
Surface Area: 792.14 acres
Percent Littoral: 43.78 %
Max Depth: 48 feet
Inlet: Morrison Brook, stream from Previs Lake, stream from Maple Lake

Summary

Hill Lake has moderate public use and 5 upstream lakes, resulting in a moderate infestation risk rating. If Zebra mussels were introduced into Hill Lake they would likely thrive due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	5 upstream Lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (245)	455	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (210)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	42.6	13	>30
pH*		8.2	233	8.2-8.8
Alkalinity*	mg/L	148.8	21	100-280
Specific Conductance*	uS/cm	305.1	61	>110
Secchi Depth	ft	13.5	60	6.56-13.12
Chlorophyll a	ug/L	11.1	19	2.5-8
Total Phosphorus	ug/L	26.8	36	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.7 (884)	>32 C	High
Dissolved oxygen	9.61 (59)	<7 mg/L	High

Lake Risk Assessment Summary: Horseshoe Lake (Shamrock)

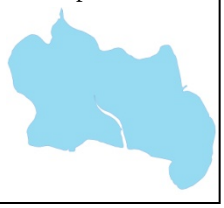
Infestation Risk Rating: Low

1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low

1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of McGregor
Surface Area: 237 acres
Percent Littoral: 68.02 %
Max Depth: 12 feet
Inlet: Musselshell Creek



Summary

Horseshoe Lake has low public use and 2 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Horseshoe Lake they could be limited by unsuitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	2 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (94)	124	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Silt, Gravel	40.8, 33.3, 18.3 13.3	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.3	33	8.2-8.8
Alkalinity*	mg/L	48	3	100-280
Specific Conductance*	uS/cm	97	34	>110
Secchi Depth	ft	3.3	94	6.56-13.12
Chlorophyll a	ug/L	20.8	31	2.5-8
Total Phosphorus	ug/L	42.7	43	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.9 (80)	>32 C	High
Dissolved oxygen	8.6 (111)	<7 mg/L	High

Lake Risk Assessment Summary: Little Pine Lake (FI TWP)

Infestation Risk Rating: Moderate
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 220 acres
Percent Littoral: 45.52 %
Max Depth: 44 feet
Inlet: Ripple River

Summary

Little Pine Lake has low public use and 11 upstream lakes, resulting in a moderate infestation risk rating. If Zebra mussels were introduced into Little Pine Lake they would likely do moderately well due to low nutrients (phosphorus and chlorophyll a) and alkalinity.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	11 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (966)	186	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (120)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Rubble	35.0, 22.5, 10.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.0	4	8.2-8.8
Alkalinity*	mg/L	83.3	3	100-280
Specific Conductance*	uS/cm	223.3	24	>110
Secchi Depth	ft	16.3	253	6.56-13.12
Chlorophyll a	ug/L	2.2	13	2.5-8
Total Phosphorus	ug/L	19	14	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 (119)	>32 C	High
Dissolved oxygen	7.95 (24)	<7 mg/L	High

Lake Risk Assessment Summary: Lone Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Low Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 433 acres
Percent Littoral: 38.15 %
Max Depth: 60.5 feet
Inlet: None

Summary

Lone Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Lone Lake, they could be limited by low nutrients, alkalinity and pH.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (215)	365	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (150)		
Substrate Suitability (mean abundance, DNR)		Sand, Rubble	NA	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.9	11	8.2-8.8
Alkalinity*	mg/L	38.4	7	100-280
Specific Conductance*	uS/cm	118	12	>110
Secchi Depth	ft	23.1	687	6.56-13.12
Chlorophyll a	ug/L	1.4	13	2.5-8
Total Phosphorus	ug/L	9.2	12	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

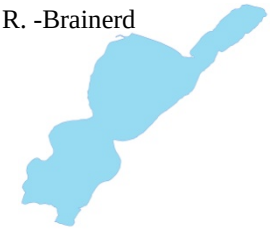
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.3 (468)	>32 C	High
Dissolved oxygen	7.81 (233)	<7 mg/L	High

Lake Risk Assessment Summary: Long Lake (Glen TWP)

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: East of Aitkin
Surface Area: 433 acres
Percent Littoral: 31.56 %
Max Depth: 117 feet
Inlet: stream from Spring Lake, 2 headwater stream



Summary

Long Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Long Lake they would do moderately well due to low pH and alkalinity. Testing for calcium in Long Lake would help to better determine its suitability to Zebra mussels.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (205)	280	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Rubble	46.7, 32.7, 16.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.65	2	8.2-8.8
Alkalinity*	mg/L	76	2	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	11.25	241	6.56-13.12
Chlorophyll a	ug/L	4.9	10	2.5-8
Total Phosphorus	ug/L	20.7	11	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	24 (32)	>32 C	High
Dissolved oxygen	3.72 (32)	<7 mg/L	Low

Lake Risk Assessment Summary: Loon (Townline) Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of Tamarack
Surface Area: 34.19 acres
Percent Littoral: 63.04 %
Max Depth: 21 feet
Inlet: None

Summary

Loon Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Loon Lake they would likely be limited by water chemistry (low calcium, pH, specific conductance and alkalinity).

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (6)	66	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	1.38	1	>30
pH*		6.7	3	8.2-8.8
Alkalinity*	mg/L	5.4	2	100-280
Specific Conductance*	uS/cm	15.3	2	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	12.41	1	2.5-8
Total Phosphorus	ug/L	34	2	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Mallard Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 417 acres
Percent Littoral: 100 %
Max Depth: 5 feet
Inlet: 3 headwater streams

Summary

Mallard Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Mallard Lake they would likely be limited by water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (15)	90	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.38	2	8.2-8.8
Alkalinity*	mg/L	43.5	2	100-280
Specific Conductance*	uS/cm	106.5	2	>110
Secchi Depth	ft	2.8	2	6.56-13.12
Chlorophyll a	ug/L	1.5	1	2.5-8
Total Phosphorus	ug/L	20.5	2	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	23.06 (2)	>32 C	High
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Minnewawa Lake

Infestation Risk Rating: High
1. Connectivity: Moderate Risk
2. Public Use: Moderate Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: Moderate Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of McGregor
Surface Area: 2355.19 acres
Percent Littoral: 87.82 %
Max Depth: 20 feet
Inlet: Stream from Horseshoe Lake

Summary

Minnewawa Lake has high public use and three upstream lakes, resulting in a high infestation risk rating. If Zebra mussels were introduced into Minnewawa Lake they would likely thrive due to suitable water chemistry. The substrates in the lake are mainly soft, but due to 707 parcels, there are docks and lifts that could act as hard surfaces for Zebra mussel attachment.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	3 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (707)	1,232	High
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (525)		
Substrate Suitability (mean abundance, DNR)		[Docks] Muck, Sand, Detritus	44.6, 33.3, 22.5	Moderate

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.0	86	8.2-8.8
Alkalinity*	mg/L	45.9	20	100-280
Specific Conductance*	uS/cm	120	84	>110
Secchi Depth	ft	5.3	259	6.56-13.12
Chlorophyll a	ug/L	9.6	23	2.5-8
Total Phosphorus	ug/L	32.1	79	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

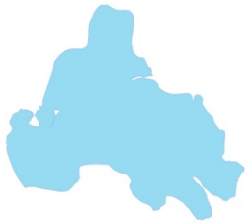
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.7 (308)	>32 C	High
Dissolved oxygen	9.46 (50)	<7 mg/L	High

Lake Risk Assessment Summary: Moulton Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Pine R.
Location: East of Emily
Surface Area: 257.87 acres
Percent Littoral: 85.31 %
Max Depth: 24 feet
Inlet: None



Summary

Moulton Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Moulton Lake they would likely be limited by water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (10)	70	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Gravel	40.8, 27.5, 22.5	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		6.6	3	8.2-8.8
Alkalinity*	mg/L	7.6	3	100-280
Specific Conductance*	uS/cm	34	1	>110
Secchi Depth	ft	4.6	1	6.56-13.12
Chlorophyll a	ug/L	9.3	1	2.5-8
Total Phosphorus	ug/L	7.5	2	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	19.5 (6)	>32 C	High
Dissolved oxygen	11.5 (1)	<7 mg/L	High

Lake Risk Assessment Summary: Nord Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Low Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 418.16 acres
Percent Littoral: 65.05 %
Max Depth: 29 feet
Inlet: 2 headwater streams

Summary

Nord Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Nord Lake they may be limited by low pH, alkalinity and specific conductance.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (111)	246	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (135)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Muck, Rubble	51.3, 30.0, 28.7, 23.3	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.7	18	8.2-8.8
Alkalinity*	mg/L	17.7	9	100-280
Specific Conductance*	uS/cm	75.3	16	>110
Secchi Depth	ft	10.1	132	6.56-13.12
Chlorophyll a	ug/L	6.5	21	2.5-8
Total Phosphorus	ug/L	19.5	24	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

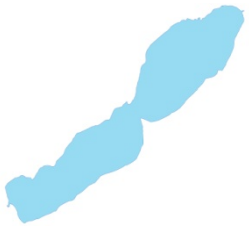
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.83 (154)	>32 C	High
Dissolved oxygen	9.27 (10)	<7 mg/L	High

Lake Risk Assessment Summary: Pine Lake (Wagner TWP)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Kettle R.
Location: West of Finlayson
Surface Area: 377.76 acres
Percent Littoral: 25.85 %
Max Depth: 27 feet
Inlet: headwater streams



Summary

Pine Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Pine Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (223)	403	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (180)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Rubble	51.7, 28.3, 12.5	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	16	8.2-8.8
Alkalinity*	mg/L	82.7	9	100-280
Specific Conductance*	uS/cm	162.2	16	>110
Secchi Depth	ft	6.2	550	6.56-13.12
Chlorophyll a	ug/L	13.3	23	2.5-8
Total Phosphorus	ug/L	32.0	23	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.4 (120)	>32 C	High
Dissolved oxygen	8.61 (11)	<7 mg/L	High

Lake Risk Assessment Summary: Portage Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 316 acres
Percent Littoral: 99.43 %
Max Depth: 17.9 feet
Inlet: Stream from Turner Lake

Summary

Portage Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Portage Lake they would likely be somewhat limited by water chemistry. Collecting the missing water chemistry parameters below would allow for a better assessment.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (76)	106	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Silt	65.8, 28.3, 17.5	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	4.6	76	6.56-13.12
Chlorophyll a	ug/L	13.2	6	2.5-8
Total Phosphorus	ug/L	23.5	6	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Rabbit Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 214 acres
Percent Littoral: 36.39 %
Max Depth: 51 feet
Inlet: Rabbit Creek

Summary

Rabbit Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Rabbit Lake they would likely thrive due to suitable water chemistry and substrate. Collecting the missing water chemistry parameters below would allow for a better assessment.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (94)	154	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Silt, Rubble	36.7, 30.0, 20.0, 9.2	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	10.5	599	6.56-13.12
Chlorophyll a	ug/L	3.7	30	2.5-8
Total Phosphorus	ug/L	12.3	30	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Rat Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of McGregor
Surface Area: 431.3 acres
Percent Littoral: 90.19 %
Max Depth: 21 feet
Inlet: headwater streams

Summary

Rat Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Rat Lake they would likely do moderately well due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (38)	53	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (15)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand	50.0, 41.7	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	10	8.2-8.8
Alkalinity*	mg/L	71	4	100-280
Specific Conductance*	uS/cm	147	9	>110
Secchi Depth	ft	5.3	188	6.56-13.12
Chlorophyll a	ug/L	9.6	12	2.5-8
Total Phosphorus	ug/L	26.9	14	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.6 (64)	>32 C	High
Dissolved oxygen	9.68 (8)	<7 mg/L	High

Lake Risk Assessment Summary: Remote Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of Tamarack
Surface Area: 132 acres
Percent Littoral: 93.94 %
Max Depth: 47 feet
Inlet: Stream from Loon Lake

Summary

Remote Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Remote Lake they would likely be limited by calcium, pH, alkalinity and specific conductance.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (8)	98	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		Muck, Gravel, Rubble	NA	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	11.8	1	>30
pH*		6.4	3	8.2-8.8
Alkalinity*	mg/L	2.8	3	100-280
Specific Conductance*	uS/cm	16.5	2	>110
Secchi Depth	ft	7.0	11	6.56-13.12
Chlorophyll a	ug/L	6.2	12	2.5-8
Total Phosphorus	ug/L	19.2	13	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	21.8 (1)	>32 C	High
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Ripple Lake (Nordland TWP)

Infestation Risk Rating: Moderate
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 629.24 acres
Percent Littoral: 53.53 %
Max Depth: 39 feet
Inlet: Ripple River

Summary

Ripple Lake has low public use and 22 upstream lakes, resulting in a moderate infestation risk rating. If Zebra mussels were introduced into Ripple Lake they would likely do moderately well due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	22 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (122)	257	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (135)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Detritus, Gravel, Rubble	32.7, 23.8, 22.6, 21.4, 13.1	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.0	15	8.2-8.8
Alkalinity*	mg/L	76	6	100-280
Specific Conductance*	uS/cm	176.5	15	>110
Secchi Depth	ft	5.5	122	6.56-13.12
Chlorophyll a	ug/L	14.2	20	2.5-8
Total Phosphorus	ug/L	30.2	20	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

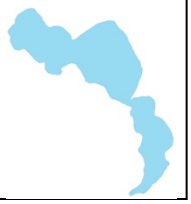
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27 (215)	>32 C	High
Dissolved oxygen	9.19 (10)	<7 mg/L	High

Lake Risk Assessment Summary: Rock Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: West of McGregor
Surface Area: 317 acres
Percent Littoral: 92.83 %
Max Depth: 13 feet
Inlet: Stream from Bass Lake,
2 headwater streams



Summary

Rock Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Rock Lake they would likely be limited by water chemistry. More than one data point for pH and alkalinity would be helpful in improving the confidence of the suitability rating.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (78)	168	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (90)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.6	1	8.2-8.8
Alkalinity*	mg/L	48	1	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	3.21	7	6.56-13.12
Chlorophyll a	ug/L	29.2	1	2.5-8
Total Phosphorus	ug/L	34	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

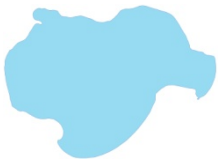
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	19 (3)	>32 C	High
Dissolved oxygen	12.5 (1)	<7 mg/L	High

Lake Risk Assessment Summary: Round Lake (Hazelton TWP)

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics 0204
Major Watershed: Rum R.
Location: North of Garrison
Surface Area: 733.13 acres
Percent Littoral: 45.06 %
Max Depth: 121.6 feet
Inlet: Stream from Big Pine L.



Summary

Round Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into Round Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (137)	257	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (120)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt, Rubble	83.3, 45.6 , 10.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.4	22	8.2-8.8
Alkalinity*	mg/L	123.3	3	100-280
Specific Conductance*	uS/cm	274.3	22	>110
Secchi Depth	ft	10.8	476	6.56-13.12
Chlorophyll a	ug/L	3.0	24	2.5-8
Total Phosphorus	ug/L	12.0	23	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26 (211)	>32 C	High
Dissolved oxygen	13.94 (2)	<7 mg/L	High

Lake Risk Assessment Summary: Round Lake (Shamrock TWP)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics 0023
Major Watershed: Mississippi R. -Grand Rapids
Location: NW of Tamarack
Surface Area: 553.5 acres
Percent Littoral: 96.86 %
Max Depth: 27 feet
Inlet: None

Summary

Round Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Round Lake they would likely be limited by water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (190)	340	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (150)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt	83.3, 30.8	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.2	2	8.2-8.8
Alkalinity*	mg/L	24.9	2	100-280
Specific Conductance*	uS/cm	62	1	>110
Secchi Depth	ft	15.1	352	6.56-13.12
Chlorophyll a	ug/L	1.9	7	2.5-8
Total Phosphorus	ug/L	14.0	21	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

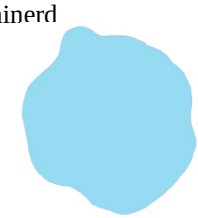
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Round Lake (Waukenabo TWP)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Moderate
1. Water Chemistry: Moderate Risk
2. Substrate: High Risk

Characteristics 0137
Major Watershed: Mississippi R. -Brainerd
Location: East of Emily
Surface Area: 633.8 acres
Percent Littoral: 63.71 %
Max Depth: 58.9 feet
Inlet: 1 headwater stream



Summary

Round Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Round Lake they would likely do moderately well due to water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (167)	287	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (120)		
Substrate Suitability (mean abundance, DNR)		Sand, Boulder, Rubble, Gravel	83.3, 18.9, 11.1, 10.6	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	1	8.2-8.8
Alkalinity*	mg/L	84	1	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	15.8	276	6.56-13.12
Chlorophyll a	ug/L	2.4	15	2.5-8
Total Phosphorus	ug/L	11.0	16	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	20 (12)	>32 C	High
Dissolved oxygen	12 (1)	<7 mg/L	High

Lake Risk Assessment Summary: Savanna Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Grand Ra
Location: North of Tamarack
Surface Area: 85.59 acres
Percent Littoral: 73.61 %
Max Depth: 23 feet
Inlet: West Savanna River

Summary

Savanna Lake has low public use and 7 upstream lakes, resulting in a low infestation risk rating. Zebra mussel establishment would likely be limited by water chemistry. The phosphorus and chlorophyll a are too high and the pH, alkalinity and specific conductance are too low.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	7 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (11)	41	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		Sand, Muck, Gravel	46.7, 30.0, 25.0,	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.45	1	8.2-8.8
Alkalinity*	mg/L	40	1	100-280
Specific Conductance*	uS/cm	90	1	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	33	1	2.5-8
Total Phosphorus	ug/L	58	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	
Dissolved oxygen	NA	<7 mg/L	

Lake Risk Assessment Summary: Section 12 Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 170 acres
Percent Littoral: 52.35 %
Max Depth: 40 feet
Inlet: Sisabagamah Creek,
1 headwater stream

Summary

Section 12 Lake has low public use and 2 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Section 12 Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	2 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (81)	231	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (150)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Detritus, Rubble	74.2, 16.7, 15.0, 10.0	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	1	8.2-8.8
Alkalinity*	mg/L	55	1	100-280
Specific Conductance*	uS/cm	119	1	>110
Secchi Depth	ft	8.4	98	6.56-13.12
Chlorophyll a	ug/L	5.5	10	2.5-8
Total Phosphorus	ug/L	20.1	10	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

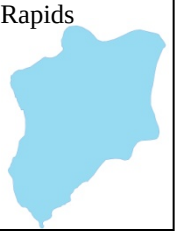
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Shumway Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: North of Tamarack
Surface Area: 74.8 acres
Percent Littoral: 59.25 %
Max Depth: 23 feet
Inlet: None



Summary

Shumway Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Shumway Lake they would likely be limited by water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (7)	37	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.0	2	8.2-8.8
Alkalinity*	mg/L	11.7	2	100-280
Specific Conductance*	uS/cm	35	1	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	20	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Sissabagamah Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 365 acres
Percent Littoral: 62.61 %
Max Depth: 37 feet
Inlet: Sisabagamah Creek

Summary

Sissabagamah Lake has low public use and 4 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Sissabagamah Lake they could be limited by water chemistry. More data would be helpful in being more confident in the suitability rating as there was only one data point for pH and alkalinity.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	4 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (42)	282	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (240)		
Substrate Suitability (mean abundance, DNR)		Sand, Detritus, Clay	76.7, 22.5, 19.2	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		7.2	1	8.2-8.8
Alkalinity*	mg/L	56	1	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	8.1	11	6.56-13.12
Chlorophyll a	ug/L	5.6	12	2.5-8
Total Phosphorus	ug/L	21.3	12	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	22 (9)	>32 C	High
Dissolved oxygen	8.4 (1)	<7 mg/L	High

Lake Risk Assessment Summary: Spirit Lake

Infestation Risk Rating: High
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: South of Aitkin
Surface Area: 523.6 acres
Percent Littoral: 58.86 %
Max Depth: 48.8 feet
Inlet: Ripple River

Summary

Spirit Lake has moderate public use and 13 upstream lakes, resulting in a high infestation risk rating. If Zebra mussels were introduced into Spirit Lake they would likely thrive due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	13 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (180)	495	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (315)		
Substrate Suitability (mean abundance, DNR)		Sand, Rubble, Muck, Gravel	38.3, 17.8, 17.2, 12.8	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.3	45	8.2-8.8
Alkalinity*	mg/L	86.1	8	100-280
Specific Conductance*	uS/cm	155.8	44	>110
Secchi Depth	ft	12.9	162	6.56-13.12
Chlorophyll a	ug/L	3.1	17	2.5-8
Total Phosphorus	ug/L	13.9	21	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

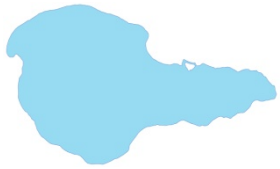
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.6 (165)	>32 C	High
Dissolved oxygen	8.6 (12)	<7 mg/L	High

Lake Risk Assessment Summary: Sugar Lake (Glen/Malmo TWPS)

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 416 acres
Percent Littoral: 66.3 %
Max Depth: 44.7 feet
Inlet: None



Summary

Sugar Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Sugar Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (119)	239	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (120)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Muck, Rubble	34.2, 30.0, 15.5, 8.3	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	26	8.2-8.8
Alkalinity*	mg/L	46.8	4	100-280
Specific Conductance*	uS/cm	156.5	6	>110
Secchi Depth	ft	14.8	264	6.56-13.12
Chlorophyll a	ug/L	3.3	16	2.5-8
Total Phosphorus	ug/L	14.3	16	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 (119)	>32 C	High
Dissolved oxygen	10.68 (3)	<7 mg/L	High

Lake Risk Assessment Summary: Swamp Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 273 acres
Percent Littoral: 100 %
Max Depth: 5 feet
Inlet: None

Summary

Swamp Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Swamp Lake they could be limited by water chemistry, but more data is needed to be confident in the suitability rating.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (11)	86	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	51.3	2	>110
Secchi Depth	ft	4.26	1	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	45.0	2	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25 (2)	>32 C	High
Dissolved oxygen	NA	<7 mg/L	

Lake Risk Assessment Summary: Taylor Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA
1. Water Chemistry: NA
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: East of Hill
Surface Area: 54.95 acres
Percent Littoral: 32.39 %
Max Depth: 84 feet
Inlet: headwater streams

Summary

Taylor Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There are no water chemistry or substrate data for Taylor Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (37)	67	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Turner Lake

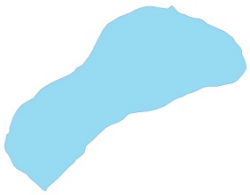
Infestation Risk Rating: Low

1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA

1. Water Chemistry: NA
2. Substrate: Low Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 63.22 acres
Percent Littoral: 77.51 %
Max Depth: 21 feet
Inlet: 3 headwater streams



Summary

Turner Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. There are no water quality data available for Turner Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (14)	74	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Muck, Sand, Detritus	51.7, 26.7, 18.3	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Twenty Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Rum R.
Location: NE of Mille Lacs Lake
Surface Area: 115 acres
Percent Littoral: 100 %
Max Depth: 4 feet
Inlet: headwater streams

Summary

Twenty Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Twenty Lake they would likely be limited by water chemistry and lake depth.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (10)	70	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	116	1	>110
Secchi Depth	ft	2.5	1	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	57.0	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	23.78 (1)	>32 C	High
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Vanduse Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Grand Rap
Location: West of Floodwood
Surface Area: 230 acres
Percent Littoral: 87.4%
Max Depth: 27feet
Inlet: None

Summary

Vanduse Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Vanduse Lake they'd likely thrive due to suitable water chemistry and substrate, although data for the additional parameters below would help in the confidence of the suitability rating.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (96)	156	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (60)		
Substrate Suitability (mean abundance, DNR)		Detritus, Muck, Sand, Gravel, Rubble	53.3, 43.3, 41.7, 24.2, 8.3	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	10.7	122	6.56-13.12
Chlorophyll a	ug/L	3.4	11	2.5-8
Total Phosphorus	ug/L	14.7	11	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Washburn Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: NA
1. Water Chemistry: NA
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: East of Hill
Surface Area: 65 acres
Percent Littoral: 93 %
Max Depth: 22 feet
Inlet: Stream from Langs Lake

Summary

Washburn Lake has low public use and one upstream lake, resulting in a low infestation risk rating. There are no water quality or substrate data for Washburn Lake, so a suitability rating was not possible.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (5)	35	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (30)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	NA	0	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Waukenabo Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: East of Emily
Surface Area: 666.09 acres
Percent Littoral: 33.87 %
Max Depth: 36.9 feet
Inlet: stream from West Lake

Summary

Waukenabo Lake has low public use and 5 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Waukenabo Lake, they would likely thrive due to suitable water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	5 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (132)	252	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (120)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt, Gravel, Muck, Rubble	65.6, 27.2, 23.3, 13.9, 9.4	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.1	25	8.2-8.8
Alkalinity*	mg/L	102.5	4	100-280
Specific Conductance*	uS/cm	189.3	9	>110
Secchi Depth	ft	6.6	188	6.56-13.12
Chlorophyll a	ug/L	16.0	17	2.5-8
Total Phosphorus	ug/L	31.7	17	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28.41 (93)	>32 C	High
Dissolved oxygen	9.66 (9)	<7 mg/L	High

Lake Risk Assessment Summary: White Elk Lake

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Grand Rapids
Location: East of Emily
Surface Area: 854 acres
Percent Littoral: 100 %
Max Depth: 4 feet
Inlet: stream from Mud Lake

Summary

White Elk Lake has low public use and one upstream lake, resulting in a low infestation risk rating. If Zebra mussels were introduced into White Elk Lake they would likely be limited by water chemistry.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	1 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (15)	90	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (75)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		6.5	2	8.2-8.8
Alkalinity*	mg/L	15.4	2	100-280
Specific Conductance*	uS/cm	44.5	2	>110
Secchi Depth	ft	2.0	1	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	27.0	2	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	21.2 (1)	>32 C	High
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Wilkins Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: High Risk

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: West of McGregor
Surface Area: 348.08 acres
Percent Littoral: 30.45%
Max Depth: 39 feet
Inlet: 2 headwater streams

Summary

Wilkins Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced into Wilkins Lake they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (139)	244	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (105)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel, Rubble	58.7, 18.0, 11.3	High

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.3	14	8.2-8.8
Alkalinity*	mg/L	63.6	10	100-280
Specific Conductance*	uS/cm	159.1	43	>110
Secchi Depth	ft	14.2	96	6.56-13.12
Chlorophyll a	ug/L	4.0	20	2.5-8
Total Phosphorus	ug/L	21.0	32	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.52 (195)	>32 C	High
Dissolved oxygen	9.49 (10)	<7 mg/L	High

Lake Risk Assessment Summary: Wladimaraf Lake (Section 10)

Infestation Risk Rating: Low
1. Connectivity: Moderate Risk
2. Public Use: Low Risk

Suitability Risk Rating: High
1. Water Chemistry: High Risk
2. Substrate: NA

Characteristics
Major Watershed: Mississippi R. -Brainerd
Location: SE of Aitkin
Surface Area: 434.47 acres
Percent Littoral: 98.09%
Max Depth: 17 feet
Inlet: Sisabagamah Creek,
1 headwater stream

Summary

Wladimaraf Lake has low public use and 3 upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced to Wladimaraf Lake they would likely thrive due to suitable water chemistry. Collecting the additional water quality parameters below would help in the confidence of the suitability rating.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of Lakes	3 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (47)	182	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (135)		
Substrate Suitability (mean abundance, DNR)		NA	NA	NA

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Specific Conductance*	uS/cm	NA	0	>110
Secchi Depth	ft	9.3	9	6.56-13.12
Chlorophyll a	ug/L	3.6	11	2.5-8
Total Phosphorus	ug/L	18.9	11	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

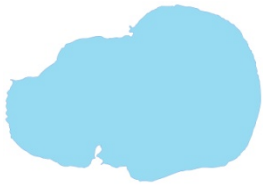
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Lake Risk Assessment Summary: Wolf Lake

Infestation Risk Rating: Low
1. Connectivity: Low Risk
2. Public Use: Low Risk

Suitability Risk Rating: Low
1. Water Chemistry: Low Risk
2. Substrate: Low Risk

Characteristics
Major Watershed: St. Louis R.
Location: North of Tamarack
Surface Area: 173.43 acres
Percent Littoral: 95.56%
Max Depth: 30.3feet
Inlet: None



Summary

Wolf Lake has low public use and no upstream lakes, resulting in a low infestation risk rating. If Zebra mussels were introduced to Wolf Lake they would likely be limited by water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (9)	9	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (0)		
Substrate Suitability (mean abundance, DNR)		Silt, Detritus, Muck	55.0, 50.0, 25.0	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		6.9	2	8.2-8.8
Alkalinity*	mg/L	16.4	2	100-280
Specific Conductance*	uS/cm	45	1	>110
Secchi Depth	ft	NA	0	6.56-13.12
Chlorophyll a	ug/L	NA	0	2.5-8
Total Phosphorus	ug/L	60	1	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	NA	>32 C	NA
Dissolved oxygen	NA	<7 mg/L	NA

Results and Discussion

Results

The lakes in Aitkin County resulted in differing infestation and suitability risk ratings (Table 10). In general terms, the headwaters lakes came out with the lowest infestation risk ratings because they have no water bodies upstream. Of the selected lakes assessed in this report, the headwaters lakes that also had low public use include Ball Bluff, Big Pine, Blackface, Blue, Cedar (Idun Twp), Clear, Esquagamah, Hammal, Hanson, Hay, Lone, Loon, Mallard, Moulton, Nord, Pine, Rat, Round (Shamrock), Round (Waukenabo), Shumway, Sugar, Swamp, Taylor, Turner, Twenty, Vanduse, Wilkins and Wolf. Lakes that had moderate infestation risk ratings had the combination of moderate public use and being in the middle of a chain of lakes (Table 10, Figure 7).

Lakes with high infestation risk ratings include Big Sandy, Farm Island, Cedar (Aitkin Twp), Minnewawa, Hickory, and Spirit Lakes (Figure 7). These lakes each have numerous upstream lakes, so have high risk from connectivity. These lakes also have a very high public use, especially Big Sandy and Minnewawa (Figure 6). Big Sandy Lake has the highest total of resort units, public accesses, and property owners of any lakes in the county (Table 3). Public use risks come from both lake visitors via boats and lake property owners via boats, boat lifts, docks and other water-related equipment.

About half of the lakes in Aitkin County resulted in a high Zebra mussel suitability rating (Figure 8). The lakes in northwest and north central Minnesota are considered hardwater lakes from glacial deposits of calcium carbonate (limestone) (Wetzel 2001). Most of the lakes in this study had suitable water chemistry for some Zebra mussel growth and development. In some of the more oligotrophic lakes, such as Clear and Lone, Zebra mussels could be limited by food (chlorophyll a). In addition, some lakes, including Big Sandy, Hammal, Horseshoe, Loon, Mallard, Moulton, Nord, Remote, Rock, Round (Shamrock), Savanna, Shumway, Sissabagamah, White Elk, and Wolf, had pH, alkalinity and conductivity, which could be limiting to Zebra mussel growth. Testing calcium in these lakes would help further determine the suitability of the lake to Zebra mussels.

Big Sandy Lake, especially, should be monitored this summer for calcium, alkalinity, pH and specific conductance. Because it is a high risk infestation lake, it would be helpful to know with more confidence how suitable it is to Zebra mussels.

The limiting factor that resulted in some lakes receiving a moderate or low suitability rating was substrate. Zebra mussels are not able to attach silt, muck, and sand directly. In areas with these substrates, the Zebra mussels will attach to plants, native mussels, and pieces of wood or stones (Karatayev et al. 1998). They will also attach to each other in clumps. Therefore, lakes that have predominantly silt, muck and sand have a low substrate suitability rating. In addition, in lakes that tend to be more eutrophic, such as Twenty and Savanna, Zebra mussels have a low suitability. Zebra mussels do not thrive in eutrophic lakes like they do in mesotrophic lakes (Karatayev et al. 1998, Nelepa 1992).

The rivers, such as the Mississippi River, are pathways for the spread of Zebra mussels downstream. Zebra mussel establishment in streams is limited by turbulence and flow, therefore the river itself is likely not a major source of zebra mussels. If lakes in a chain are less than a mile apart, Zebra mussels from an infested lake are likely to move downstream and infest downstream lakes.

Lake Mille Lacs was determined to be infested in 2005. It is an inconvenient infestation for the region, as there are many lakes nearby Mille Lacs and Mille Lacs is such a destination lake. It is encouraging, however, that no other lakes in Aitkin County have been infested with Zebra mussels in the 10 years since they've been established in Mille Lacs. Inspections of boats leaving Lake Mille Lacs for plants, water, and Zebra mussels is very important to limit the spread, along with offering decontamination opportunities from the DNR, County or private business.

Lakes like Farm Island, where boaters go if Mille Lacs is too windy, should have access inspectors also to make sure no plants, water, or Zebra mussels are coming in from Lake Mille Lacs.

Table 10. Summary of risk ratings and prioritized recommendations taking into account the risk.

Lake Name	Lake ID	Public Use Risk	Infestation Risk	Suitability Risk	AIS Program Prioritized Recommendations
Aitkin	01-0040-00	Low	Low	Moderate	1. Education
Ball Bluff	01-0046-00	Low	Low	Moderate	1. Education
Big Pine	01-0157-00	Low	Low	High	1. Education
Big Sandy	01-0062-00	High	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Blackface	01-0045-00	Low	Low	NA	1. Education
Blind	01-0188-00	Low	Low	Moderate	1. Education
Blue	01-0181-00	Low	Low	NA	1. Education
Cedar (Aitkin/FI TWPS)	01-0209-00	Moderate	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Cedar (Idun TWP)	01-0065-00	Low	Low	Moderate	1. Education
Clear (Glen TWP)	01-0093-00	Low	Low	NA	1. Education
Cutaway	01-0056-00	Low	Low	NA	1. Education
Dam	01-0096-00	Low	Low	High	1. Education
Elm Island	01-0123-00	Low	Moderate	Moderate	1. Education
Esquagamah	01-0147-00	Low	Low	Moderate	1. Education
Farm Island	01-0159-00	Moderate	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Fleming	01-0105-00	Low	Low	Moderate	1. Education
French	01-0104-00	Low	Low	High	1. Education
Gun	01-0099-00	Low	Low	High	1. Education
Hammal	01-0161-00	Low	Low	Moderate	1. Education
Hanging Kettle	01-0170-00	Low	Moderate	Moderate	1. Education
Hanson	01-0132-00	Low	Low	Moderate	1. Education
Hay	01-0059-00	Low	Low	Moderate	1. Education

Table 10 continued on the next page…

Table 10 continued. Summary of risk ratings and prioritized recommendations taking into account the risk.

Lake Name	Lake ID	Public Use Risk	Infestation Risk	Suitability Risk	AIS Program Prioritized Recommendations
Hickory	01-0179-00	Moderate	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Hill	01-0142-00	Moderate	Moderate	High	1. Public Access Inspections 2. Education
Horseshoe	01-0034-00	Low	Low	Low	1. Education
Little Pine	01-0176-00	Low	Moderate	Moderate	1. Education
Lone	01-0125-00	Low	Low	Moderate	1. Education
Long	01-0089-00	Low	Low	Moderate	1. Education
Loon	01-0024-00	Low	Low	Low	1. Education
Mallard	01-0149-00	Low	Low	Low	1. Education
Minnewawa	01-0033-00	High	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Moulton	01-0212-00	Low	Low	Low	1. Education
Nord	01-0117-00	Low	Low	Moderate	1. Education
Pine	01-0001-00	Low	Low	High	1. Education
Portage	01-0069-00	Low	Low	Moderate	1. Education
Rabbit	01-0091-00	Low	Low	High	1. Education
Rat	01-0077-00	Low	Low	Moderate	1. Education
Remote	01-0038-00	Low	Low	Low	1. Education
Ripple	01-0146-00	Low	Moderate	High	1. Education
Rock	01-0072-00	Low	Low	Low	1. Education
Round (Hazelton TWP)	01-0204-00	Low	Low	High	1. Education
Round (Shamrock TWP)	01-0023-00	Low	Low	Low	1. Education
Round (Waukenabo TWP)	01-0137-00	Low	Low	Moderate	1. Education
Savanna	01-0014-00	Low	Low	Low	1. Education
Section 12	01-0120-00	Low	Low	High	1. Education
Shumway	01-0015-00	Low	Low	Low	1. Education

Table 10 continued on the next page…

Table 10 continued. Summary of risk ratings and prioritized recommendations taking into account the risk.

Lake Name	Lake ID	Public Use Risk	Infestation Risk	Suitability Risk	AIS Program Prioritized Recommendations
Sissabagamah	01-0129-00	Low	Low	Low	1. Education
Spirit	01-0178-00	Moderate	High	High	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Sugar	01-0087-00	Low	Low	High	1. Education
Swamp	01-0092-00	Low	Low	NA	1. Education
Taylor	01-0109-00	Low	Low	NA	1. Education
Turner	01-0074-00	Low	Low	NA	1. Education
Twenty	01-0085-00	Low	Low	Low	1. Education
Vanduse	01-0058-00	Low	Low	High	1. Education
Washburn	01-0111-00	Low	Low	NA	1. Education
Waukenabo	01-0136-00	Low	Low	High	1. Education
White Elk	01-0148-00	Low	Low	Low	1. Education
Wilkins	01-0102-00	Low	Low	High	1. Education
Wladimaraf (Section 10)	01-0115-00	Low	Low	High	1. Education
Wolf	01-0019-00	Low	Low	Low	1. Education

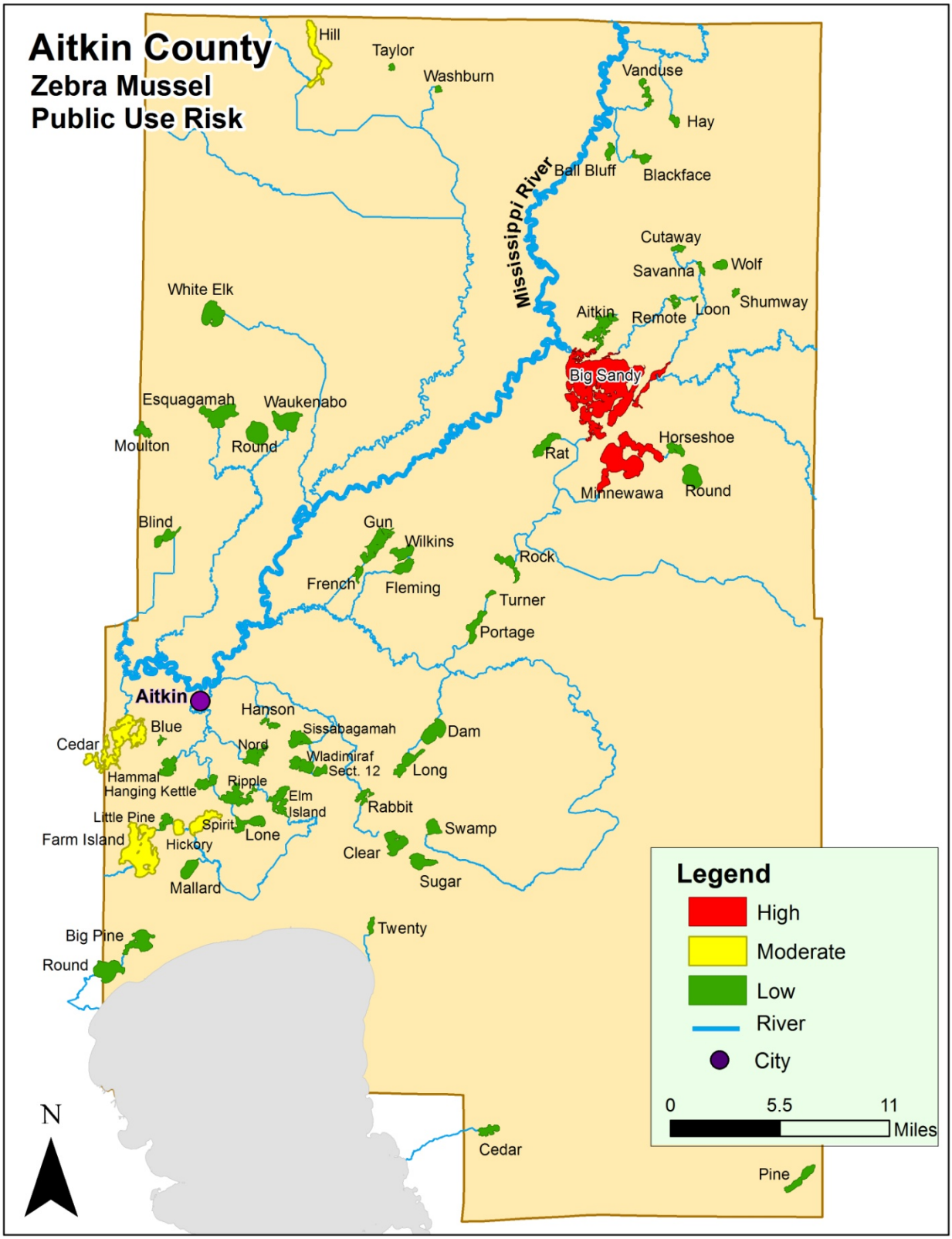


Figure 6. Public use risk rating for lakes in Aitkin County.

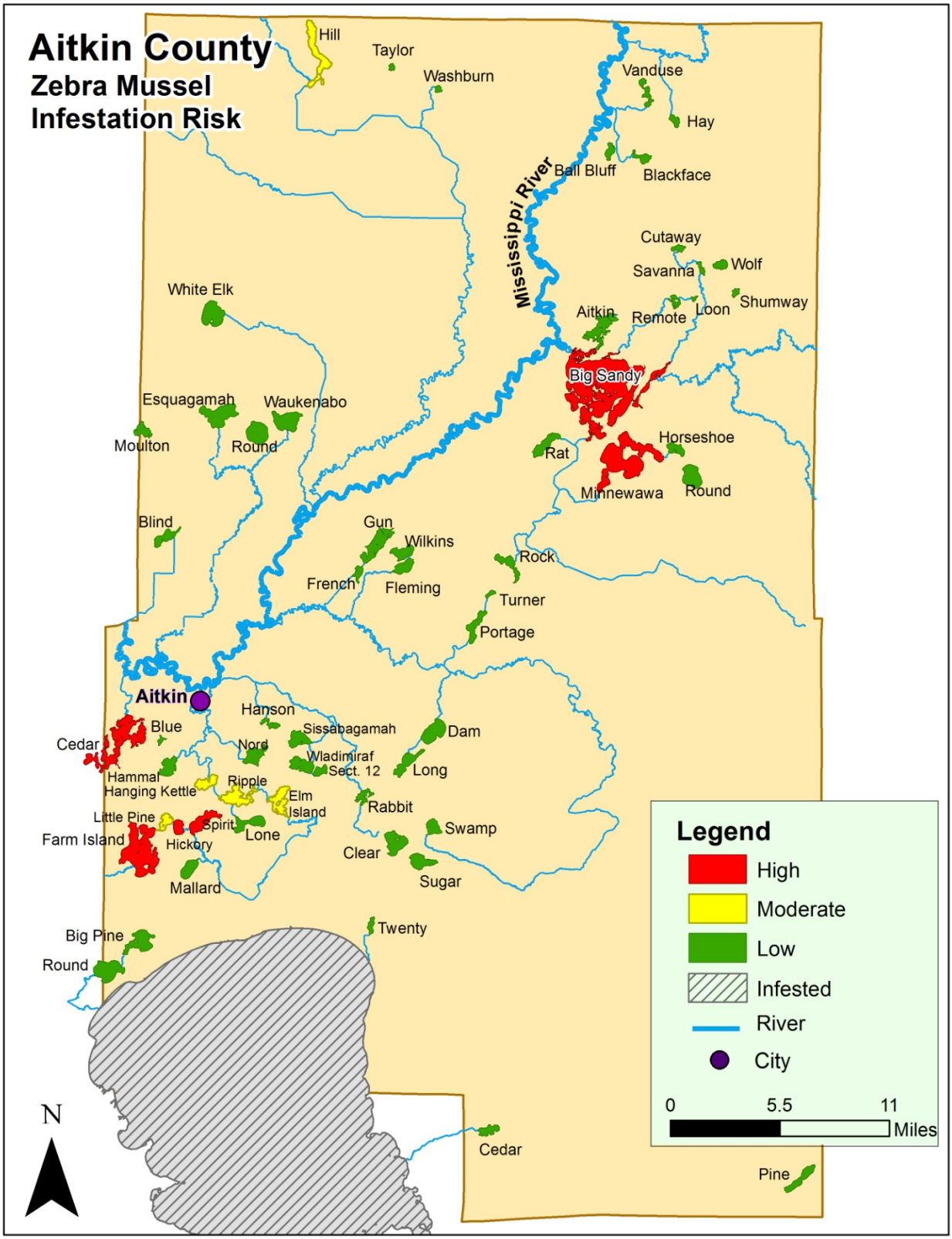


Figure 7. Overall Zebra mussel infestation risk rating in Aitkin County.

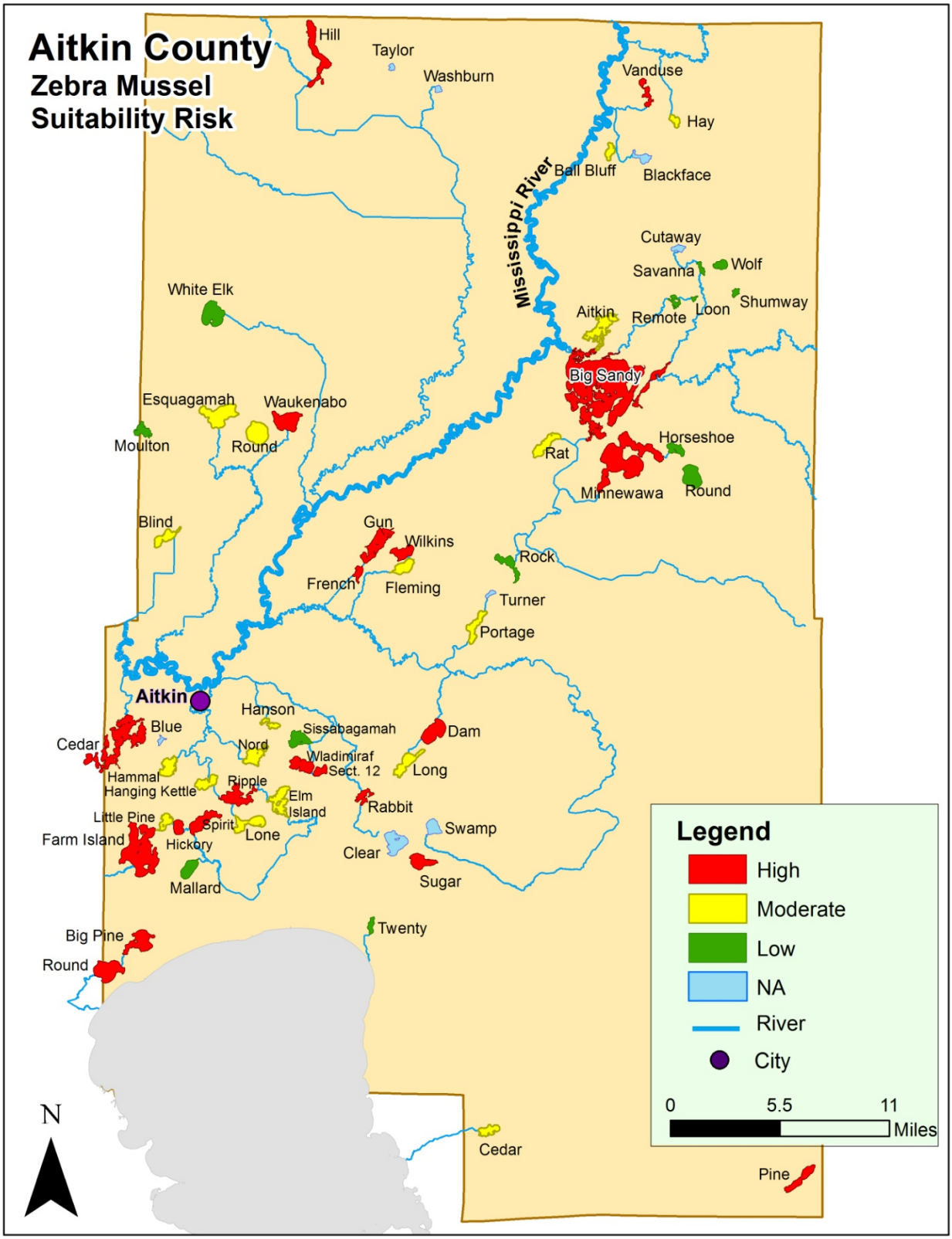


Figure 8. Overall Zebra mussel suitability risk rating in Aitkin County.

Data Gaps

This study identified some data gaps in Aitkin County. Calcium is the most important water chemistry parameter when evaluating Zebra mussel habitat suitability. Many lakes did not have any historical calcium data. Since they are hardwater lakes, it can be presumed that their calcium is high enough for Zebra mussel survival, but it is better to have the actual data numbers for evaluation. It is recommended that this data be collected to assist with overall verification of water chemistry. The data gaps are indicated on the lake report cards. See the table below for a summary of parameters needed for each lake (Table 11).

Table 11. Summary of data gaps for water bodies in Aitkin County.

Lake Name	Lake ID	Parameters Needed
Aitkin	01-0040-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Ball Bluff	01-0046-00	pH, Specific Conductance, Temp, Dissolved Oxygen
Big Pine (Hazelton)	01-0157-00	Calcium
Big Sandy	01-0062-00	Calcium
Blackface	01-0045-00	Calcium, pH, Alkalinity, Specific Conductance, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Blind	01-0188-00	Calcium
Blue	01-0181-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Cedar (Aitkin/FI TWPS)	01-0209-00	Calcium
Cedar(Idun TWP)	01-0065-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Clear (Glen TWP)	01-0093-00	Calcium
Cutaway	01-0056-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Dam	01-0096-00	Calcium
Elm Island	01-0123-00	Calcium
Esquagamah	01-0147-00	Calcium
Farm Island	01-0159-00	Calcium
Fleming	01-0105-00	Calcium
French (Fleming TWP)	01-0104-00	Calcium, Specific Conductance
Gun	01-0099-00	Calcium
Hammal	01-0161-00	Calcium
Hanging Kettle	01-0170-00	Calcium
Hanson	01-0132-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Hay	01-0059-00	Calcium, Specific Conductance
Hickory	01-0179-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Hill (Hill Lake TWP)	01-0142-00	none
Horseshoe (Shamrock)	01-0034-00	Calcium
Little Pine (Farm Island TWP)	01-0176-00	Calcium
Lone	01-0125-00	Calcium

Table 11 continued on next page…

Table 11 continued. Summary of data gaps for water bodies in Aitkin County

Lake Name	Lake ID	Parameters Needed
Long (Glen TWP)	01-0089-00	Calcium, Specific Conductance
Loon (Townline)	01-0024-00	Secchi, Temp, Dissolved Oxygen
Mallard	01-0149-00	Calcium, Dissolved Oxygen
Minnewawa	01-0033-00	Calcium
Moulton	01-0212-00	Calcium
Nord	01-0117-00	Calcium
Pine (Wagner TWP)	01-0001-00	Calcium
Portage	01-0069-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Rabbit	01-0091-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Rat	01-0077-00	Calcium
Remote	01-0038-00	Dissolved Oxygen
Ripple (Nordland TWP)	01-0146-00	Calcium
Rock	01-0072-00	Calcium, Specific Conductance
Round (Hazelton TWP)	01-0204-00	Calcium
Round (Shamrock TWP)	01-0023-00	Calcium, Temp, Dissolved Oxygen
Round (Waukenabo TWP)	01-0137-00	Calcium, Specific Conductance
Savanna	01-0014-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Section 12	01-0120-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Shumway	01-0015-00	Calcium, Secchi, Chlorophyll-a, Temp, Dissolved Oxygen
Sissabagamah	01-0129-00	Calcium, Specific Conductance
Spirit	01-0178-00	Calcium
Sugar (Glen/Malmo TWPS)	01-0087-00	Calcium
Swamp	01-0092-00	Calcium, pH, Alkalinity, Chlorophyll-a, Dissolved Oxygen
Taylor	01-0109-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Turner	01-0074-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Twenty	01-0085-00	Calcium, pH, Alkalinity, Chlorophyll-a, Dissolved Oxygen
Vanduse	01-0058-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Washburn	01-0111-00	Calcium, pH, Alkalinity, Specific Conductance, Secchi, Chlorophyll-a, Total Phosphorus, Temp, Dissolved Oxygen
Waukenabo	01-0136-00	Calcium
White Elk	01-0148-00	Calcium, Chlorophyll-a, Dissolved Oxygen
Wilkins	01-0102-00	Calcium
Wladimaraf (Section 10)	01-0115-00	Calcium, pH, Alkalinity, Specific Conductance, Temp, Dissolved Oxygen
Wolf	01-0019-00	Calcium, Secchi, Chlorophyll-a, Temp, Dissolved Oxygen

Vectors of Spread – Infestation Routes

In order to have a watershed strategy for AIS program management, the vectors of spread for each lake needs to be determined. This risk assessment process also identifies the vectors of spread for the lakes in the watershed. For headwaters lakes there is no risk of infestation from upstream, so any new infestation would come from lake users (boats, boat lifts, docks, etc). For lakes in a river chain, both lake users and upstream lakes need to be considered as potential vectors of spread.

Zebra mussels can be transferred from infested waters through several different pathways. These pathways are highly dependent upon the time of year and the stage in the Zebra mussel life cycle. The risk pathway ratings for time of year are shown in Table 12.

1. Connectivity via a river or stream.
   An upstream infested lake is almost certain to infest downstream lakes if the stream distance between lakes is short enough.

2. Transfer of equipment from lake to lake.
   The transfer of a large breeding adult Zebra mussel population from one lake to another on an infested boat lift, dock, swim raft or other water-related equipment has a very high probability of infesting a lake.

3. Transfer of mussels hitchhiking on vegetation or mud on boat and trailers.
   The risk of hitchhiking mussels depends somewhat on the time of year. When vegetation dies off in the fall, the Zebra mussels fall off into the sediments. Therefore, Zebra mussels are only attached to plants from approximately June to September. Zebra mussels can't be transferred alone in mud because they do not thrive in soft substrates; they need to be attached to a hard surface.

4. Transfer of veligers or mussels from live wells, bilges, and any area of the boat that holds water.
   The risk of veliger transfer depends greatly on the time of year. In infested lakes in northwest Minnesota, it has been documented that Zebra mussel veligers are at peak concentrations in early July (Rufer 2015). *Therefore, July is the month of the year where veliger transfer from lake to lake has the highest risk for infestation. Research has shown that veligers are non-existent during the ice-covered season, so there is essentially no risk of veliger transfer in the winter* (Rufer 2015).

5. Transfer of juvenile mussels on boats not thoroughly cleaned after being tied up on infested waters for an extended period of time.
   The risk of mussel transfer on boats is highest in July through September, because that is when the mussels are reproducing and settling on new hard surfaces.

6. Transfer of veligers and juvenile mussels on swimwear, SCUBA equipment, waders or other gear used in water.
   The risk of veliger transfer on gear depends somewhat on the time of year. July and August would be the times of highest risk throughout the year. Overall, this pathway is considered to be very low risk potential because the amount of water transferred is so small.

Risk – Time of Year

The risk of Zebra mussel infestation varies by the time of year. Data sources show that in Minnesota, the time of year that has the highest concentration of Zebra mussel veligers matches up with the highest use time for the public (Figures 23-24, Pesch & Bussiere 2014, Rufer 2015). The implications of these data indicate that additional prevention measures should be implemented during July to prevent Zebra mussel spread.

In Pesch and Busierre's (2014) survey of 2nd Homeowners in Central and West Central Minnesota, the highest use time of year was July, at an average of 16 days during that month (Figure 23, Pesch & Bussiere 2014). Rufer's monitoring of Zebra mussel veligers in Pelican Lake, a Zebra mussel infested lake in Otter Tail County, shows the peak density for Zebra mussels is in July (Figure 24, Rufer 2015).

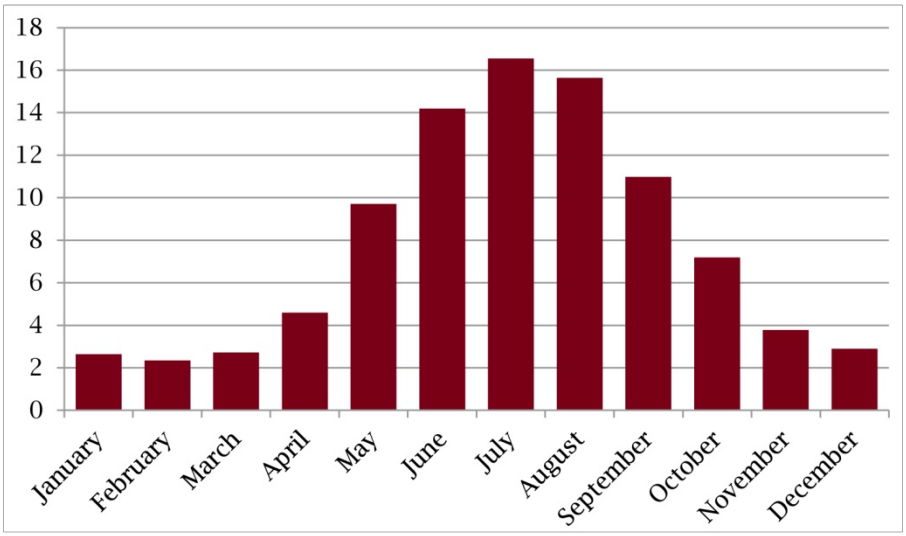


Figure 9. Average number of days occupied per month (n=552) from Pesch & Bussiere 2014.

The full report can be downloaded from this link:
http://www.extension.umn.edu/community/research/reports/docs/2014-2nd-Homeowners.pdf

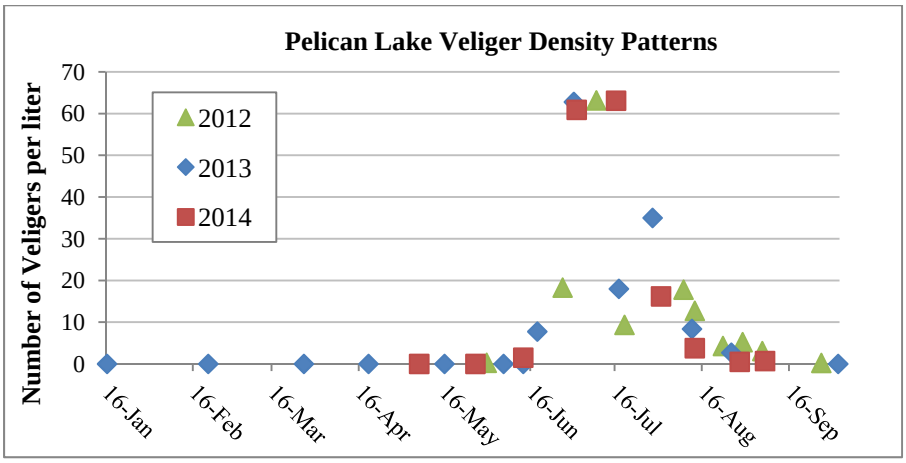


Figure 10. Veliger densities in Pelican Lake, 2012-2014 from Rufer 2015.

The full report can be downloaded from this link:
http://pgolid.org/wp-content/uploads/2014/01/PGOLID-Veliger-Report-2012-2014.pdf

Table 12. Summary of risk pathways depending on the time of year. The Zebra mussel life stage for the pathway is indicated in italics.

	Typical Minnesota Open Water Season							Typical Minnesota Ice-covered season				
Risk Pathway	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**March**
1. Connectivity via a river or stream.	insignificant	insignificant	Low *Veligers*	High *Veligers*	Moderate *Veligers*	Low *Veligers*	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant
2. Transfer of equipment from lake to lake.	insignificant	insignificant	Moderate *Adults & juveniles*	High *Adults & juveniles*	High *Adults & juveniles*	Low *Adults & juveniles*	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant
3. Transfer of mussels hitchhiking on vegetation or mud on boats, trailers and gear.	Low *Adults & juveniles*	Low *Adults & juveniles*	Moderate *Adults & juveniles*	High *Adults & juveniles*	High *Adults & juveniles*	Moderate *Adults & juveniles*	Low *Adults & juveniles*	insignificant	insignificant	insignificant	insignificant	insignificant
4. Transfer of veligers via water in boats (live wells, bilges, etc) and float planes.	insignificant	insignificant	Low *Veligers*	High *Veligers*	Moderate *Veligers*	Low *Veligers*	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant
5. Transfer of juvenile mussels on boats not thoroughly cleaned after being tied up on infested waters for an extended period of time.	insignificant	insignificant	Moderate *Adults & juveniles*	High *Adults & juveniles*	High *Adults & juveniles*	Moderate *Adults & juveniles*	Low *Adults & juveniles*	insignificant	insignificant	insignificant	insignificant	insignificant
6. Transfer of veligers and juvenile mussels on swimwear, SCUBA equipment, waders or other gear used in water.	insignificant	insignificant	Low *Veligers*	High *Veligers*	Moderate *Veligers*	Low *Veligers*	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant

Sources: Zebra mussel veliger time-of-year risk was taken from Rufer 2015.
Zebra mussel adult and juvenile time-of-year risk was taken from Mackie & Claudi 201, Mackie 1996, McMahon 1996.

AIS Program Management Recommendations

In an ideal world, all Aquatic Invasive Species (AIS) prevention programs would be applied to all lakes. In reality, budgets are always limited, so prioritization of programs due to risk ratings is necessary. Due to the differing risk ratings, programs can be individualized to fit each lake's risk category (Table 13). Lakes with high public use ratings should be at the highest priority for boat inspections at public accesses. Lakes that are already infested should have boat-washing stations nearby for decontamination. All lakes should be targeted with a watershed-wide education program. Because the highest risk time of the summer and one of the highest tourism times of the summer intersect on 4th of July week, focus *additional* targeted education and outreach during this time of year. For monitoring, ideally all lakes would be monitored for adult Zebra mussels because if trained volunteers are used there is no monetary cost, but there is a large benefit.

The assessments in this report result combine the report cards with the risk of time of year (Figure 12) in the following specific Aquatic Invasive Species Program Management Recommendations (Table 13). This portion of the report can be inserted directly into the county's AIS Plan, and guide the use of the county's AIS funds in the most efficient and effective way possible.

Table. 13. Framework for the watershed's AIS plan.

Activity	Target Lakes	Target Time of Year	Who	Cost	Narrative
Watercraft Inspections	Priority 1: • Mille Lacs • Big Sandy • Minnewawa Priority 2: • Farm Island • Cedar • Hickory • Spirit • Hill	Priority 1: July Priority 2: August	County	TBD	This activity depends on available funding. If limited funding is available, focus inspections on the high risk public use lakes (Big Sandy and Minnewawa) and the infested lakes (Mille Lacs) in July. If more funding is available, add in moderate public use risk lakes (Farm Island, Cedar, Hickory, Spirit, Hill) in July. Next, add in August inspections, and next priority 3 lakes (highest scores of the low public use risk lakes).
Water Quality Monitoring	See Table 11 for data gaps.	May – September	Lake Associations	TBD	Monitor lakes for missing parameters shown in Table 11. Priority parameters for each lake would be Calcium, Alkalinity, pH and Specific Conductance as they have the most effect on Zebra mussel suitability. Big Sandy Lake would be first priority for monitoring Calcium, Alkalinity, pH and Specific Conductance as it is a high risk infestation lake.

Table 13 continued on the next page…

Table. 13 continued. Framework for the watershed's AIS plan.

Activity	Target Lakes	Target Time of Year	Who	Cost	Narrative
Early Detection Monitoring: *Zebra mussel veligers*	• Big Sandy • Minnewawa • Farm Island • Cedar • Hickory • Spirit	July	County or Lake Associations	$540	Collect plankton tow samples in high infestation risk lakes in early and late July for veliger analysis. Early detection allows for possible treatment.
Early Detection Monitoring: *Adult Zebra mussels*	Priority 1: • Big Sandy • Minnewawa • Farm Island • Cedar • Hickory • Spirit Priority 2: • Ripple • Elm Island • Hanging Kettle • Little Pine • Hill Priority 3: All lakes	Priority 1: September Priority 2: Every other week from late June to mid-September	Volunteers, Lake Associations	$0	a. In September, conduct a lake-wide inspection of docks and boat lifts as they are removed from the lake. b. Place a cinder block in 5-8 feet of water near the public access and any other heavily used areas of the lake, and have the volunteers check the block (pull it up or snorkel) every other week from late June to mid-September. Record results on the MN DNR's website: http://www.dnr.state.mn.us/volunteering/zebramussel_monitoring/report.html

Table 13 continued on the next page…

Table. 13 continued. Framework for the watershed's AIS plan.

Activity	Target Lakes	Target Time of Year	Who	Cost	Narrative
Monitoring: Invasive Plants	Priority 1: • Big Sandy • Minnewawa Priority 2: • Farm Island • Cedar • Hickory • Spirit	Mid to late June	County, Lake Associations, or private contractor	TBD	Conduct plant surveys to look for aquatic invasive plants. Mid to late June will catch Curly-leaf pondweed, Flowering rush, and Eurasian watermilfoil.
Education and Outreach	All	Priority 1: 4th of July week Priority 2: Memorial day to labor day Priority 3: Year round	County and watershed	TBD	Conduct a consistent watershed-wide education program to schools and the general public. In high tourism areas such as Aitkin, focus ***additional*** education around 4th of July since that is the highest risk time of the year for spread.
Decontamination	Mille Lacs	Priority 1: July Priority 2: August	County, DNR, or private business	TBD	Provide decontamination opportunities for boats leaving infested lakes. Inform boaters on where the decontamination station is located.

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