Wild Rice River Watershed

AIS Prioritization

A planning tool developed for AIS risk management and prevention

2014

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

RED RIVER BASIN COMMISSION

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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.

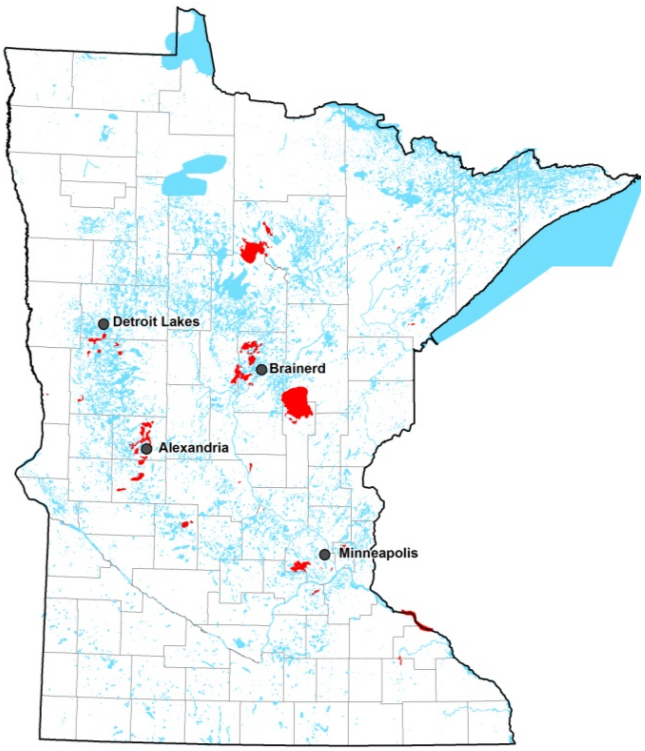


Figure 1. Minnesota Lakes infested by Zebra mussels, 2014.

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 2015, 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

The goals of this project were to assess the risk of Zebra mussel infestation in the Wild Rice River Watershed in order to prioritize funding and efforts to prevent the further spread of Zebra mussels. 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 16). 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 Wild Rice, forms a major watershed. A group of major watersheds that flow into a common river, such as the Red River, form a basin. A group of basins that flow into a common river form a divide.

The Red River of the North Basin stretches from northeastern South Dakota and west-central Minnesota northward through eastern North Dakota and northwestern Minnesota into southern Manitoba. It ends where the Red River empties into the southern end of Lake Winnipeg.

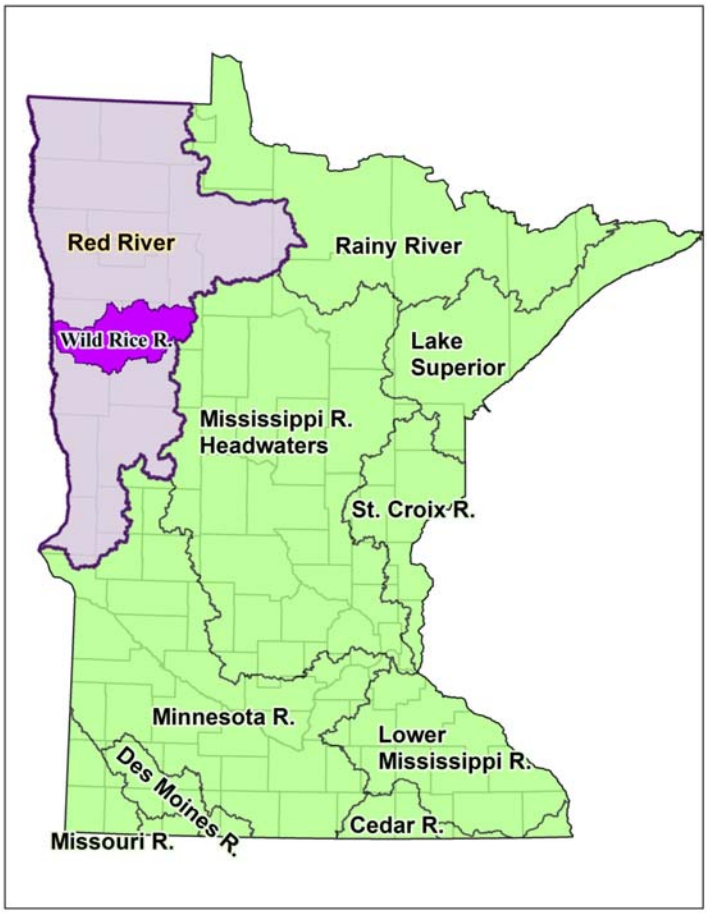


Figure 2. Minnesota showing all major drainage basins, the Red River Basin, and the Wild Rice Watershed.

The Minnesota portion of the Red River Basin covers about 37,100 square miles in northwestern Minnesota in all or part of 21 counties. It is home to about 17,842 miles of streams and 668,098 acres of lakes.

The terrain of the Red River Basin in Minnesota is very diverse; from the flat, intensively farmed plain just east of the length of the Red River, to the rolling uplands full of trees and lakes in the east-central portion of the basin, to the extensive wetlands in the northeast.

The Wild Rice River Major Watershed represents an area of about 1,629 square miles, including areas of substantial portions of Mahnomen and Norman counties, and very small portions of Clay, Becker, Polk, and Clearwater counties (Figure 3).

The Wild Rice River Watershed is a drainage basin of the Red River and the major tributaries of the watershed are Mosquito Creek, Marsh Creek, Twin Lake Creek, White Earth River, and the south branch of the Wild Rice River.

Wild Rice River Watershed

The Wild Rice River Watershed is located in the Red River Basin of the north (Figure 3). Its headwaters start in Upper Rice Lake and Mosquito Creek. From there the river flows west with other lakes such as Roy, Twin Lakes and White Earth Lake flowing into it. It joins the Red River near Halstad, MN.

There is one taxing entity, the Wild Rice River Watershed District, in the Wild Rice River Watershed that has jurisdiction over the area.

Predominate land uses / land covers are Row Crops (53%), Forest (23%), Wetlands (9%), Grass/Pasture/Hay (8%), and Residential/Commercial Development (4%). Agricultural land use in the basin is significant, accounting for over 60% of the overall watershed acres. Development pressure is moderate to considerable in some areas, with occasional farms, timberland, and lakeshore being parceled out for recreation, lake or country homes (NRCS).

As of the end of 2014, there are no aquatic invasive species infestations in the Wild Rice River Watershed.

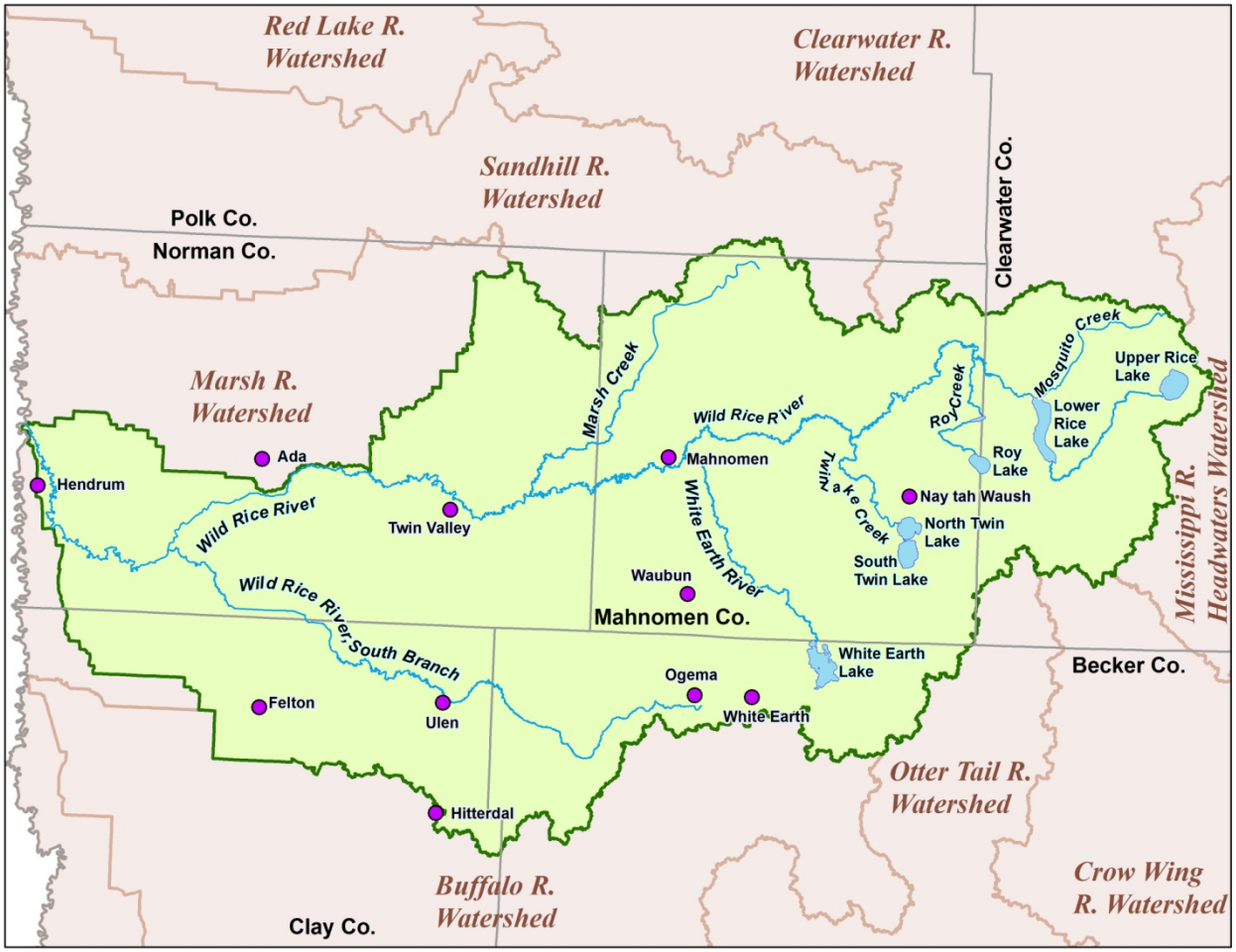


Figure 3. Wild Rice River Watershed.

Zebra Mussel Risk Assessment

Lake Methods

All the major lakes in the Wild Rice River Watershed have water chemistry, temperature, and dissolved oxygen data available (Table 1). These data were collected by lake associations, River Watch, International Water Institute, Clearwater SWCD, Mahnomen SWCD, the Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, the Wild Rice River Watershed District, and were used in the Zebra mussel risk assessment for lakes.

Table 1. Major lakes in the Wild Rice River Watershed.

Waterbody name	Lake DOW
White Earth	03-0328-00
North Twin	44-0023-00
South Twin	44-0014-00
Roy	44-0001-00
Upper Rice	15-0059-00
Lower Rice	15-0130-00

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 (<20 km apart)	Moderate risk
Upstream infested lake (<20 km apart)	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 Detroit Lakes 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 Rating
White Earth	175	75	1260	110	1620	Moderate
North Twin	63	0	1695	0	1758	Moderate
South Twin	148	150	1275	0	1573	Moderate
Roy	61	60	0	0	121	Low
Upper Rice	35	0	0	0	35	Low
Lower Rice	0	0	0	0	0	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)	0-700	701-2,000	2,000+

Water Chemistry

Available water quality data was compiled and analyzed for each major lake and stretch of river in the Wild Rice River Watershed. 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 for 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
Conductivity (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
Fubble	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 2013).

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 substate.

	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 Methods

Water chemistry data have been collected throughout the Wild Rice River Watershed by the International Water Institute, Wild Rice Watershed District, the Minnesota Pollution Control Agency, Clearwater SWCD, Mahnomen SWCD and Norman SWCD (Figures 7-8). For this assessment, the Wild Rice River and its tributaries were separated into the following sections for report cards (Table 10, Figure 4). Mosquito Creek and Roy Lake Creek did not have any water quality data, so that is why they are not included in this table.

Table 10. Wild Rice River and tributary sections in this report.

Section	Stream
1	Wild Rice River: Headwaters
2	Wild Rice River: Lower Rice Lake to Twin Lake Creek
3	Twin Lake Creek
4	Wild Rice River: Twin Lake Creek to White Earth River
5	White Earth River
6	Wild Rice River: White Earth River to Marsh Creek
7	Marsh Creek
8	Wild Rice River: Marsh Creek to South Branch
9	South Branch Wild Rice River
10	Wild Rice River: South Branch to Red River

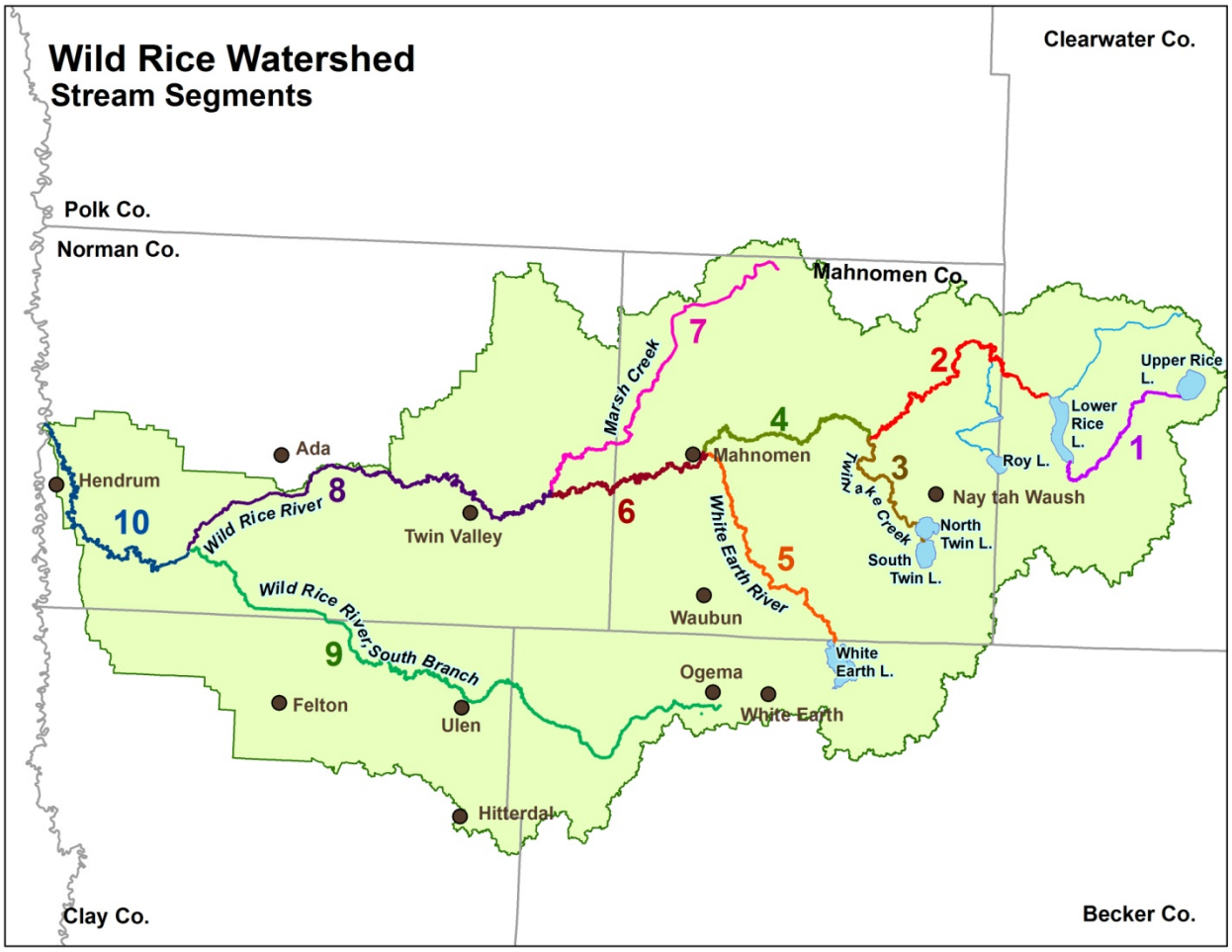


Figure 4. Numbered stream segments in this report. Text descriptions of each section can be found in Table 10.

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 (like the headwaters and tributaries of the Wild Rice River), 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 exponentially with distance in small streams (<30m wide). A small number of veligers have been found 10-18 km (6-11 miles) downstream of an infested lake in studied stream systems (Horvath *et al*.1996; Horvath & Lamberti 1999). 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 Wild Rice River is heavily vegetated, somewhat cloudy (turbid). DNR data and local observations indicate sandy substrates in the upper portion of the watershed and silty turbid substrates in the lower portion of the watershed (Appendix 1). These characteristics are limiting to Zebra mussel veliger survival. Taking into account the literature and the condition and habitat of the river, for the purposes of the risk assessment for the Wild Rice River, 32 km (20 mi) is considered the longest a veliger could theoretically travel (Table 11). 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 NTUs, 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). For the purposes of this study, the Mackie and

Claudi (2010) numbers are used as guides, but further research is needed to be more decisive conclusions can be made (Figures 5-6).

Minnesota Pollution Control Agency (MPCA) assessments have resulted in some portions of the Wild Rice River being listed as impaired for turbidity. Minnesota's turbidity standard is 25 NTUs, which is under the threshold of 80 NTUs indicated by Mackie and Claudi (2010). The portions of the river that are listed as impaired include: Marsh Creek and the main stem of the Wild Rice River from Marsh Creek to the Red River.

Infestation Risk Rating

In the Wild Rice River Watershed, the primary lakes are at the headwaters of the river, and there is considerable distance between the lakes and the main stem of the Wild Rice River. Because a continual source of Zebra mussel veligers from a lake is needed to sustain a stream population of Zebra mussels, distance from the nearest upstream lake is the limiting factor for an infested stream. The second most important factor in transporting Zebra mussel veligers is the presence of aquatic vegetation and wetlands (Bodamer & Brossenbroek 2008). In streams, public use is a larger threat to downstream lakes than the stream itself (Table 11).

Table 11. Infestation Risk Rating for streams and rivers.

	Risk Rating		
	Low	**Moderate**	**High**
Connectivity	No lakes connected	No upstream infested lakes	Upstream infested lakes
Distance from nearest upstream lake*	>32 km (20 mi)	10-32 km (6.2-20 mi)	0-10 km (0-6.2 mi)
Presence of aquatic vegetation/wetland conditions	Yes	Minimal	No
Public use	No public use	Fishing, ricing, bait harvest, waterfowl hunting, paddle sports	Motorboating, camping, fishing, bait harvest, waterfowl hunting, paddle sports
Overall rating	>32 km (20 mi) from nearest upstream lake	10-32 km (6.2-20 mi) from nearest upstream lake	0-10 km (0-6.2 mi) from nearest upstream lake

**possible limiting parameter for streams*

Suitability Risk Rating

Total suspended solids data were available from the Wild Rice River and its tributaries. Results show that the average total suspended solids are well below the threshold of 96 mg/L on most sites, although in some sites the maximum is over the threshold (Figures 5-6). Therefore, the total suspended solids are most likely not chronically limiting to Zebra mussels. It appears that flow is the main potential limiting factor to Zebra mussel establishment, so it was given the most weight when considering suitability (Table 12).

Table 12. Infestation Risk Rating for streams and rivers.

	Risk Rating Low	Moderate	High
Habitat suitability/substrate	Muddy water, silty mucky substrate	Clear to cloudy water, gravel and rocks	Clear water, rocky, very low flow
Flow rate*	High flow	Moderate flow	Low flow, dams and stagnant backwaters
Water chemistry*	Average turbidity and/or total suspended solids over the thresholds	Maximum turbidity and/or total suspended solids over the thresholds	Average and maximum turbidity and/or total suspended solids under the thresholds
Maximum temperature	>30 C	--	<30 C
Average dissolved oxygen	<7 mg/L	--	> 7 mg/L
Overall rating	High flow and high turbidity and/or total suspended solids	Moderate flow and low turbidity and/or total suspended solids; rocky substrate	Low flow, dams and backwaters and low turbidity and/or total suspended solids; rocky substrate

**possible limiting parameter for streams*

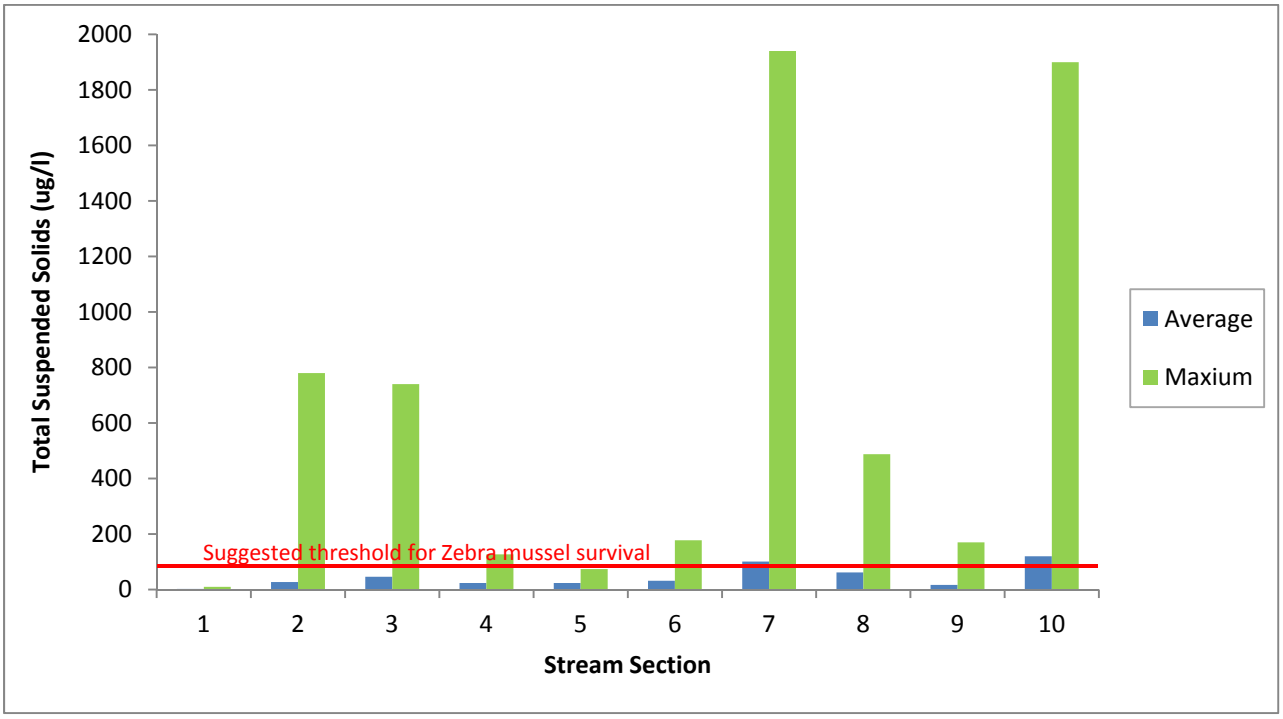


Figure 5. Total suspended solids monitoring data for each stream section in the Wild Rice River Watershed. See Table 10 and Figure 4 for reference on the stream sections.

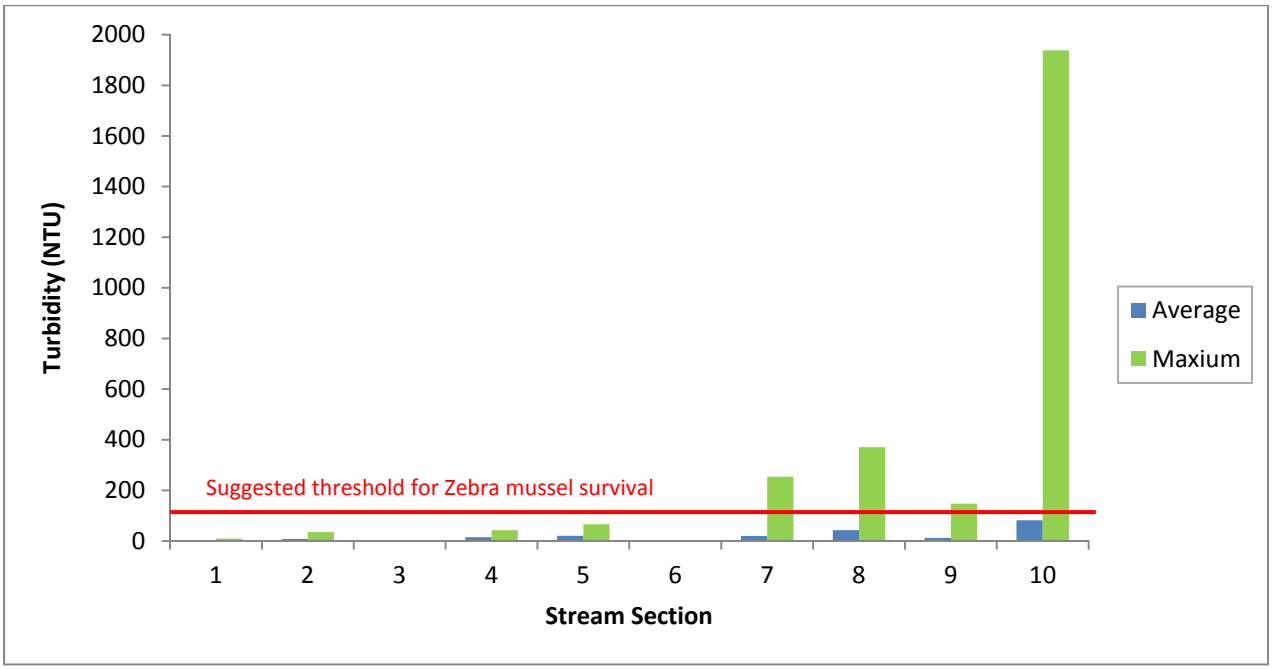


Figure 6. Turbidity monitoring data for each stream section in the Wild Rice River Watershed. See Table 10 and Figure 4 for reference on the stream sections.

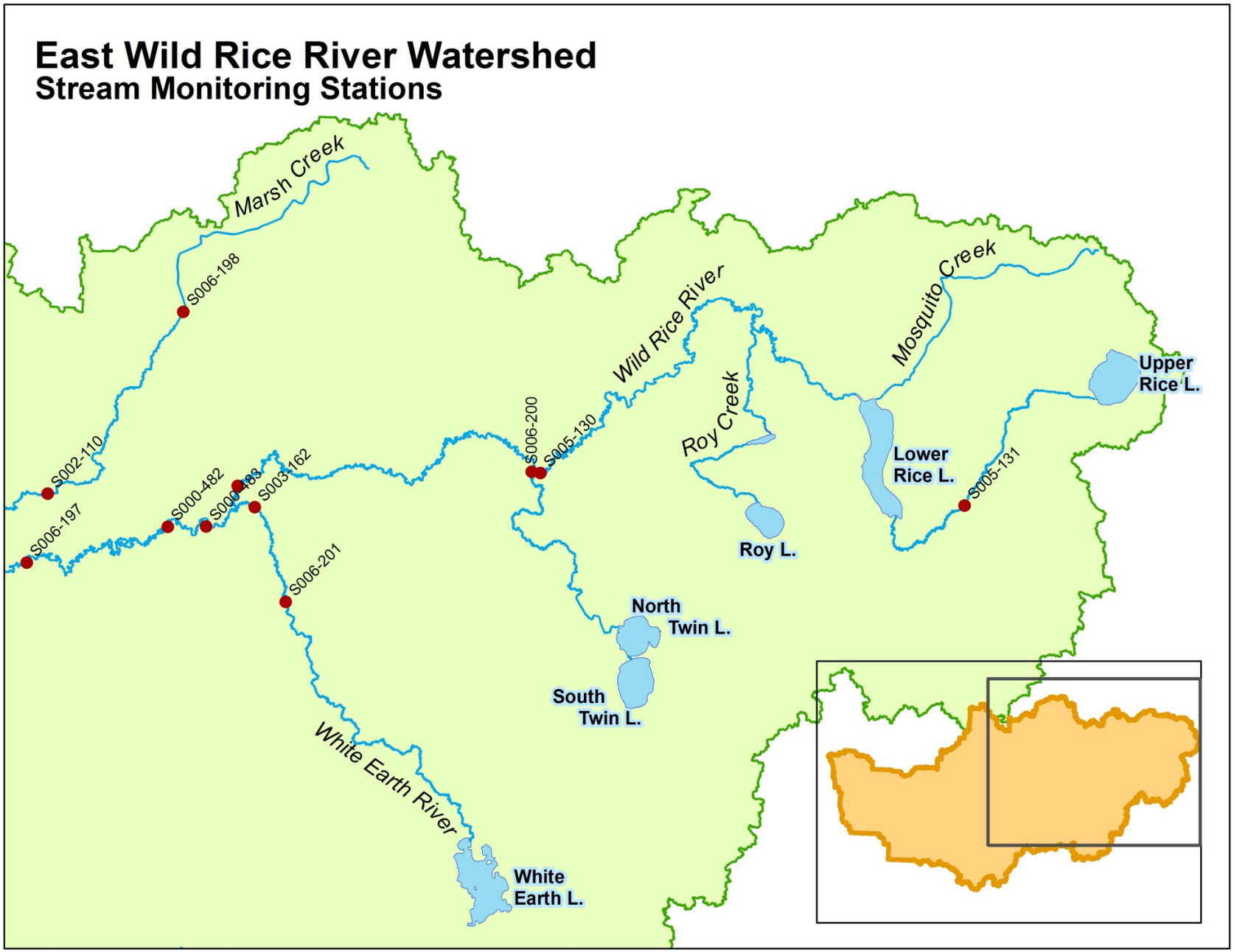


Figure 7. Wild Rice River Watershed eastern stream monitoring sites (MPCA).

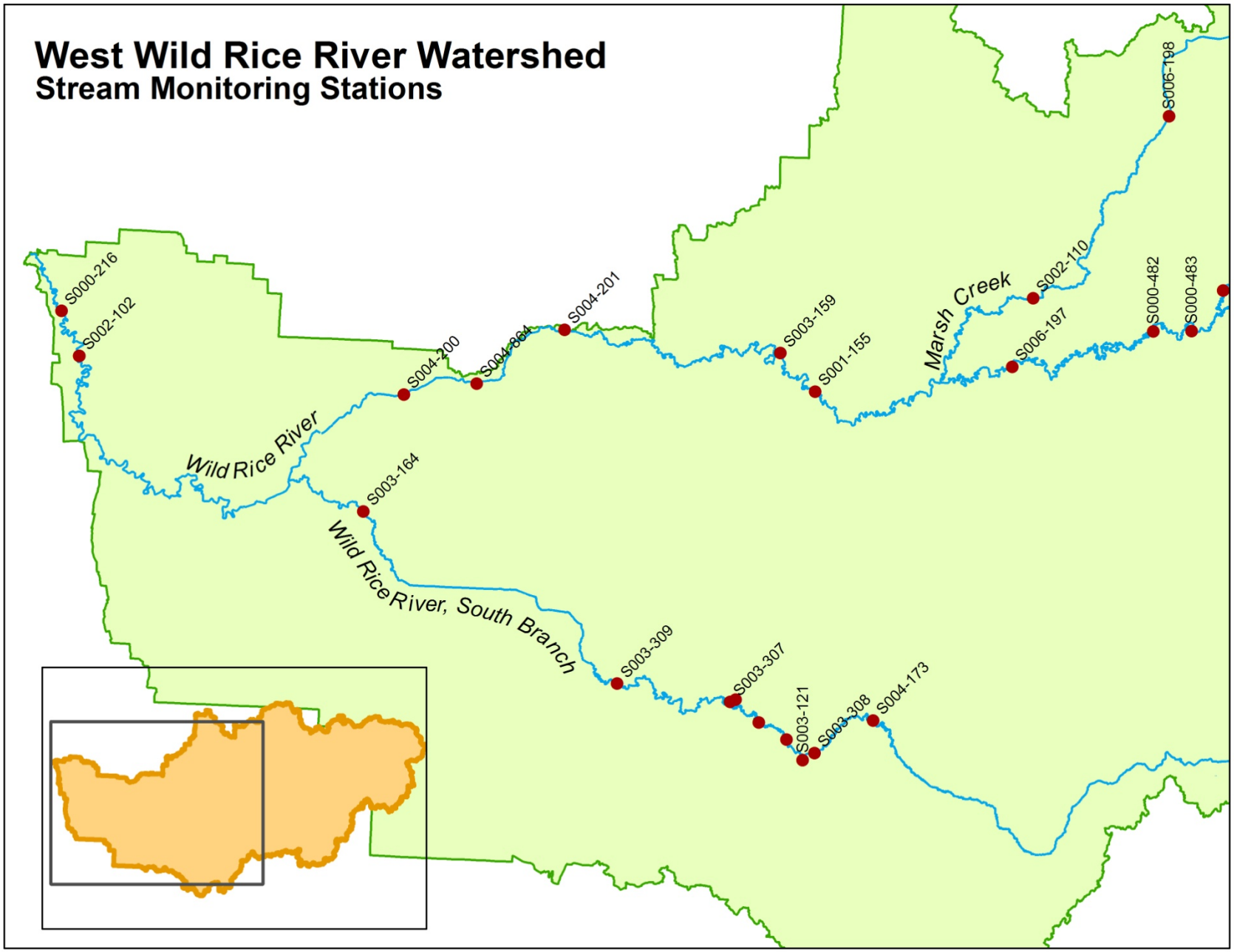


Figure 8. Wild Rice River Watershed western monitoring sites (MPCA).

Lake Risk Assessment Summary: White Earth Lake

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

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

Characteristics
Major Basin: Red River
Location: North of Detroit Lakes
Surface Area: 1,989 acres
Percent Littoral: 30%
Max Depth: 120 ft
Inlet: Gull Creek

Summary

White Earth Lake has an upstream lake with substantial development (Tulaby Lake), which gives it a moderate connectivity rating. It also has two resorts with cabins and RV camping spots, and a fair amount of development, giving it a moderate public use risk. If Zebra mussels were introduced into White Earth Lake, they would likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Top of watershed	2 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (175)	1,620	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (1,445)		
Substrate Suitability (mean abundance, DNR)		Rubble, Sand, Boulder	42.1, 25.4, 19.6	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
Conductivity*	uS/cm	NA	0	>110
Secchi Depth	ft	13.6	373	6.6-13.1
Chlorophyll a	ug/L	3.3	41	2.5-8.0
Total Phosphorus	ug/L	13.2	41	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	21.7 °C (5 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: North Twin Lake

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

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

Characteristics
Major Basin: Red River
Location: East of Mahnomen
Surface Area: 956 acres
Percent Littoral: 94%
Max Depth: 16 ft
Inlet: Badboy Creek & South Twin Lake

Summary

North Twin Lake is downstream from South Twin Lake, but there are no upstream lakes from South Twin Lake. There is moderate public use in North and South Twin Lakes, with two resorts and some residents. If Zebra mussels were introduced to North Twin Lake, they would do moderately well due to soft substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	1 upstream lake	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (63)	1,758	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (1695)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt, Muck	66.1, 29.4, 22.2	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.6	10	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Conductivity*	uS/cm	NA	0	>110
Secchi Depth	ft	9.28	68	6.6-13.1
Chlorophyll a	ug/L	7.4	10	2.5-8.0
Total Phosphorus	ug/L	21.4	10	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26 °C (10 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: South Twin Lake

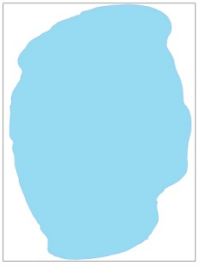
Infestation Risk Rating: Moderate

1. Connectivity: Low
2. Public Use: Moderate

Suitability Risk Rating:

1. Water Chemistry: High
2. Substrate: High

Characteristics
Major Basin: Red River
Location: East of Mahnomen
Surface Area: 1,118 acres
Percent Littoral: 47%
Max Depth: 29 ft
Inlet: 2 minor



Summary

South Twin Lake is a headwaters lake, so the main risk of infestation comes from lake residents and visitors. There is moderate public use in North and South Twin Lakes, with two resorts and some residents. If Zebra mussels were introduced into White Earth 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 (148)	1,573	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (1,425)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel	83.3%, 6.1%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	32.4	10	>30
pH*		8.5	54	8.2-8.8
Alkalinity*	mg/L	164.4	18	100-280
Conductivity*	uS/cm	295	43	>110
Secchi Depth	ft	9.86	69	6.6-13.1
Chlorophyll a	ug/L	4.3	35	2.5-8.0
Total Phosphorus	ug/L	16.2	56	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

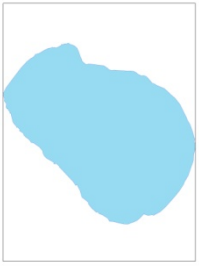
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.1 °C (404 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Roy Lake

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

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

Characteristics
Major Basin: Red River
Location: South of Bagley
Surface Area: 689 acres
Percent Littoral: 93%
Max Depth: 16 ft
Inlet: Roy Lake Creek



Summary

Roy Lake is a headwaters lake, so there is little risk of infestation from upstream. In addition, the lake has low development and public use. If Zebra mussels were to be introduced into Roy Lake, they would do moderately well due to the substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (61)	121	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, Detritus	43.3%, 42.8%, 33.9%	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.4	53	8.2-8.8
Alkalinity*	mg/L	192	5	100-280
Conductivity*	uS/cm	336.4	53	>110
Secchi Depth	ft	6.9	244	6.6-13.1
Chlorophyll a	ug/L	9.1	24	2.5-8.0
Total Phosphorus	ug/L	28	29	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

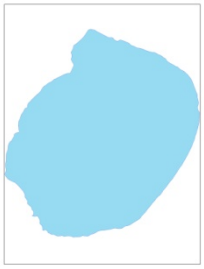
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.76 °C (54 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Upper Rice Lake

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

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

Characteristics
Major Basin: Red River
Location: South of Bagley
Surface Area: 1689 acres
Percent Littoral: 100%
Max Depth: 13 ft
Inlet: None



Summary

Upper Rice Lake is managed by the DNR for wild rice. It is a headwaters lake, so there is no upstream AIS risk. There is also very little public use and development on the lake. If Zebra mussels were introduced to the lake they would do only moderately well due to the soft substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (35)	35	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)		Unavailable, but most likely soft substrates because it is managed for wild rice	NA	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.2	18	8.2-8.8
Alkalinity*	mg/L	135	1	100-280
Conductivity*	uS/cm	267	19	>110
Secchi Depth	ft	6.8	27	6.6-13.1
Chlorophyll a	ug/L	7.0	20	2.5-8.0
Total Phosphorus	ug/L	21	21	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

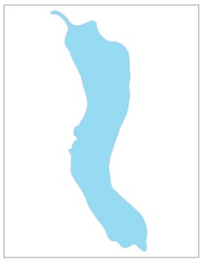
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25 °C (21 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Lower Rice Lake

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

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

Characteristics
Major Basin:
Location: South of Bagley
Surface Area: 2044 acres
Percent Littoral: 100%
Max Depth: NA
Inlet: Wild Rice River



Summary

Upper Rice Lake is managed by the DNR for wild rice. It only has one lake upstream, so there is low AIS risk. There is also no public use or development on the lake. If Zebra mussels were introduced to the lake they would do only moderately well due to the soft substrates.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	1 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (35)	35	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)		Unavailable, but most likely soft substrates because it is managed for wild rice	NA	Low

Water Chemistry Risk Summary

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
Conductivity*	uS/cm	NA	0	>110
Secchi Depth	ft	NA	0	6.6-13.1
Chlorophyll a	ug/L	NA	0	2.5-8.0
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	High
Dissolved oxygen	NA	<7 mg/L	High

Stream Risk Assessment Summary: Wild Rice River Headwaters

Infestation Risk Rating: Low

1. Connectivity: Low
2. Distance from lakes: Moderate
3. Vegetation: Low
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: High
3. Substrate: Moderate
4. Dissolved Oxygen: High

Characteristics

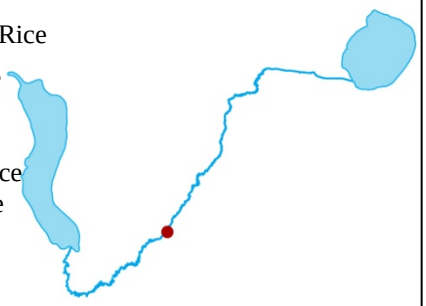
Major Basin: Wild Rice

County: Clearwater

Site: S005-131

Location: Upper Rice Lake to Lower Rice Lake

Length: 18.3 miles



Summary

The headwaters of the Wild Rice River starts in Upper Rice Lake, and then flows west through Lower Rice Lake to the Wild Rice River. This stretch of stream could become infested if Upper Rice Lake became infested, and Upper Rice Lake has a low infestation risk. Therefore, there is a low infestation risk to this reach of the Wild Rice River.

Attribute	Description	Infestation Risk
Water Connectivity	Headwaters	Low
Distance from nearest upstream lake	18.3 miles	Moderate
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Waterfowl hunting, ricing	Moderate
Habitat Suitability/Substrate	Clear water, gravel	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	26.6 (28)	>32 C	High
Dissolved oxygen average (mg/L)	9.0 (27)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	388	597	28	>110
Total Suspended Solids*	mg/L	2.8	10	20	<96
Turbidity*	NTU	3.9	9.7	36	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River at Twin Lake Creek

Infestation Risk Rating: Low

1. Connectivity: Moderate
2. Distance from lakes: Low
3. Vegetation: Low
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate
4. Dissolved Oxygen: High

Characteristics

Major Basin: Wild Rice

County: Mahnomen

Site: S005-130

Location: Lower Rice Lake to Twin Lake Creek

Length: 32.8 miles

Summary

This site on the Wild Rice River is just before Twin Lake Creek joins it. In order for Zebra mussels to be present in this location, a source (Roy or Upper/Lower Rice Lakes) would be needed to continually introduce veligers to the stream; however, those lakes are over 32.8 stream miles away. Therefore, this stretch of the river has a low infestation risk rating.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 3 uninfested lakes	Moderate
Distance from nearest upstream lake	32.8 miles	Low
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Clear water, gravel	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	26.7 (52)	>32 C	High
Dissolved oxygen average (mg/L)	9.5 (51)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	408	583	56	>110
Total Suspended Solids*	mg/L	27.6	780	47	<96
Turbidity*	NTU	8.4	35.2	42	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Twin Lake Creek

Infestation Risk Rating: Moderate

1. Connectivity: Moderate
2. Distance from lakes: Moderate
3. Vegetation: Low
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate
4. Dissolved Oxygen: High

Characteristics

Major Basin: Wild Rice

County: Mahnomen

Site: S006-200

Location: South Twin Lake to Wild Rice River

Length: 15.5 miles

Summary

Twin Lake Creek flows from South Twin Lake north into the Wild Rice River. If South and North Twin Lakes became infested, the stream could become infested. The stream flow would likely be the limiting factor for Zebra mussel survival within the stream itself. In order for Zebra mussels to be present in the stream, a source (South Twin Lake) would be needed to continually introduce veligers to the stream.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 2 uninfested lakes	Moderate
Distance from nearest upstream lake	<15.5 miles	Moderate
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, paddle sports, hunting	Moderate
Habitat Suitability/Substrate	Cloudy water, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	26.5 (21)	>32 C	High
Dissolved oxygen average (mg/L)	9.2 (21)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	364	763	22	>110
Total Suspended Solids*	mg/L	46.3	740	22	<96
Turbidity*	NTU	NA	NA	0	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River

Infestation Risk Rating: Low

1. Connectivity: Moderate
2. Distance from lakes: Low
3. Vegetation: Low
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate
4. Dissolved Oxygen: High

Characteristics

Major Basin: Wild Rice

County: Mahnomen

Site: S003-163

Location: Twin Lake Creek to White Earth River

Length: 27.1 miles

Summary

This section of the Wild Rice River runs from Twin Lake Creek to White Earth River. If South and North Twin Lakes became infested, the veligers are not likely to make it this far into the White Earth River. Therefore, the infestation risk rating for this section of stream is low.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 4 uninfested lakes	Moderate
Distance from nearest upstream lake	42.6 miles	Low
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Clear water, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	26.2 (47)	>32 C	High
Dissolved oxygen average (mg/L)	9.0 (47)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	434	572	33	>110
Total Suspended Solids*	mg/L	24	127	19	<96
Turbidity*	NTU	15	43	32	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: White Earth River

Infestation Risk Rating: Moderate

1. Connectivity: Moderate
2. Distance from lakes: Moderate
3. Vegetation: Yes
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: High
3. Substrate: Moderate
4. Dissolved Oxygen: High

Characteristics

Major Basin: Wild Rice

County: Mahnomen

Sites: S006-201
S003-162

Location: White Earth Lake to Wild Rice River

Length: 26.2 miles

Summary

The White Earth River runs from White Earth Lake to the Wild Rice River. If White Earth Lake became infested, the stream could become infested near the lake. The stream flow and vegetation would likely be the limiting factors for Zebra mussel survival within the stream itself. The distance is great enough that if White Earth Lake was infested, the veligers are not likely to make it all the way to the Wild Rice River.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 1 uninfested lakes	Moderate
Distance from nearest upstream lake	<26.2 miles	Moderate
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Cloudy water, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	25.4 (92)	>32 C	High
Dissolved oxygen average (mg/L)	8.6 (92)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	269	764	79	>110
Total Suspended Solids*	mg/L	24	74	43	<96
Turbidity*	NTU	21	66	56	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River

Infestation Risk Rating: Low

1. Connectivity: Moderate
2. Distance from lakes: Low
3. Vegetation: Moderate
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate
4. Dissolved Oxygen: High

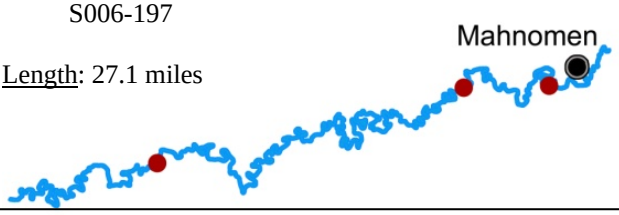
Characteristics

Major Basin: Wild Rice County: Mahnomen & Norman

Sites: S000-483
S000-482
S006-197

Location: White Earth River to Marsh Creek

Length: 27.1 miles



Summary

This section of the Wild Rice River runs from White Earth River to Marsh Creek. The distance from any upstream lakes is great enough that veligers are not likely to make it this far downstream. The stream flow would likely be the limiting factor for Zebra mussel survival within the stream itself.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 5 uninfested lakes	Moderate
Distance from nearest upstream lake	53.3 miles	Low
Presence of aquatic vegetation/wetland conditions	Minimal	Moderate
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Cloudy water, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	20 (1)	Unknown	Low
Maximum Flow (cfs)	20 (1)	Unknown	Low
Summer maximum temperature (C)	24.5 (22)	>32 C	High
Dissolved oxygen average (mg/L)	9.7 (22)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	150	150	1	>30
Hardness	Mg/L	270	270	1	100-280
Specific Conductance	uS/cm	448	821	23	>110
Total Suspended Solids*	mg/L	32	178	23	<96
Turbidity*	NTU	3	3	1	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Marsh Creek

Infestation Risk Rating: Low

1. Connectivity: Low
2. Distance from lakes: Low
3. Vegetation: Low
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Low
3. Substrate: Low
4. Dissolved Oxygen: High

Characteristics

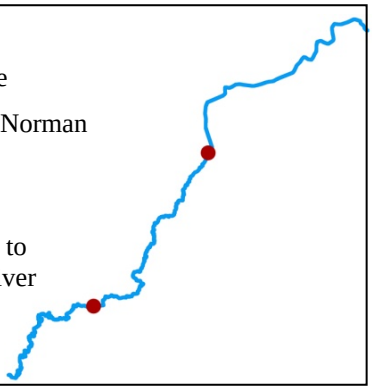
Major Basin: Wild Rice

County: Mahnomen & Norman

Sites: S002-110
S006-198

Location: Marsh Creek to Wild Rice River

Length: 33.4 miles



Summary

Marsh Creek runs from its origin to the Wild Rice River east of Twin Valley. Observations and total suspended solids results show that the creek is cloudy and turbid. Therefore, it has a low suitability to Zebra mussels. In addition, it has no lakes along its reach, so there is a low risk for Zebra mussels to infest the creek.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 0 lakes	Low
Distance from nearest upstream lake	0 upstream lakes	Low
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Muddy, cloudy water	Low

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	NA	Unknown	Low
Maximum Flow (cfs)	NA	Unknown	Low
Summer maximum temperature (C)	27.0 (92)	>32 C	High
Dissolved oxygen average (mg/L)	9.1 (92)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	637	977	79	>110
Total Suspended Solids*	mg/L	101	1,940	42	<96
Turbidity*	NTU	20	254	56	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River

Infestation Risk Rating: Low

1. Connectivity: Moderate
2. Distance from lakes: Low
3. Vegetation: Moderate
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate
4. Dissolved Oxygen: High

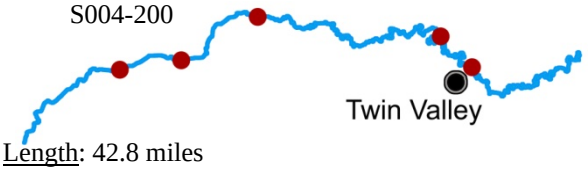
Characteristics

Major Basin: Wild Rice

County: Norman

Sites: S001-155
S004-201
S004-864
S004-200

Location: Marsh Creek to South Branch



Length: 42.8 miles

Summary

This section of the Wild Rice River runs from Marsh Creek to the South Branch of the Wild Rice River. Observations and total suspended solids results show that the creek is somewhat cloudy and turbid. Therefore, it has a low suitability to Zebra mussels. In addition, it has no lakes along its reach, so there is a low risk for Zebra mussels to infest the creek.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 5 uninfested lakes	Moderate
Distance from nearest upstream lake	96.1 miles	Low
Presence of aquatic vegetation/wetland conditions	Minimal	Moderate
Public Use	Fishing, bait harvest, paddle sports	Moderate
Habitat Suitability/Substrate	Cloudy water, sand, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	316 (31,612)	Unknown	Low
Maximum Flow (cfs)	536 (31,612)	Unknown	Low
Summer maximum temperature (C)	31.0 (155)	>32 C	High
Dissolved oxygen average (mg/L)	9.3 (146)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	64.8	75.9	7	>30
Hardness	Mg/L	242	245	2	100-280
Specific Conductance	uS/cm	501	659	144	>110
Total Suspended Solids*	mg/L	61.7	488	102	<96
Turbidity*	NTU	42.7	371	128	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River South Branch

Infestation Risk Rating: Low

1. Connectivity: Low
2. Distance from lakes: Low
3. Vegetation: Moderate
4. Public Use: Moderate

Suitability Risk Rating: Low

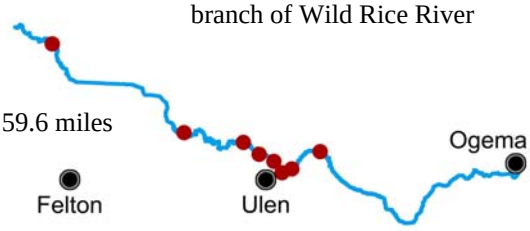
1. Flow Rate: Low
2. Water Chemistry: Moderate
3. Substrate: Moderate Risk
4. Dissolved Oxygen: High Risk

Characteristics

Major Basin: Wild Rice County: Becker, Clay, Norman

Sites: *See below Location: Ogema to main branch of Wild Rice River

Length: 59.6 miles



Summary

The South branch of the Wild Rice River runs from Ogema northwest to the main branch of the Wild Rice River. There are no large lakes connected to this river, so there aren't likely sources of Zebra mussels to infest it. *Monitored sites include: S003-164, S003-165, S003-307, S003-308, S003-309, S004-172, S004-173.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 0 lakes	Low
Distance from nearest upstream lake	0 lakes upstream	Low
Presence of aquatic vegetation/wetland conditions	Minimal	Moderate
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Cloudy water, sand, gravel, rocks	Moderate

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	36.2 (1,979)	Unknown	Low
Maximum Flow (cfs)	60 (1,979)	Unknown	Low
Summer maximum temperature (C)	29.4 (334)	>32 C	High
Dissolved oxygen average (mg/L)	9.95 (320)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	NA	NA	0	>30
Hardness	Mg/L	NA	NA	0	100-280
Specific Conductance	uS/cm	682	1,510	310	>110
Total Suspended Solids*	mg/L	16.7	170	108	<96
Turbidity*	NTU	12.8	148	268	<80

**possible limiting parameter for streams*

Stream Risk Assessment Summary: Wild Rice River Terminus

Infestation Risk Rating: Low

1. Connectivity: Moderate
2. Distance from lakes: Low
3. Vegetation: Moderate
4. Public Use: Moderate

Suitability Risk Rating: Low

1. Flow Rate: Low Risk
2. Water Chemistry: Low Risk
3. Substrate: Low Risk
4. Dissolved Oxygen: High Risk

Characteristics

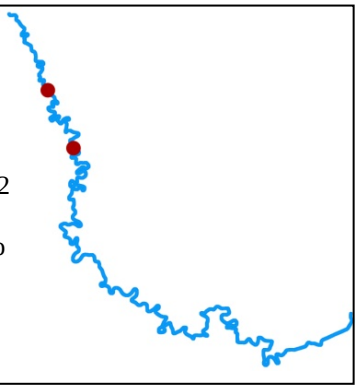
Major Basin: Wild Rice

County: Norman

Sites: S000-216, S002-102

Location: South Branch to Red River

Length: 30.5 miles



Summary

The final stretch of the Wild Rice River runs from the south branch to its pour point into the Red River. This stretch of the river is very fast flowing and turbid, which could be unsuitable to Zebra mussels. It is listed as impaired for turbidity by the Minnesota Pollution Control Agency. In addition, it has no lakes along its reach, so there are aren't likely sources of Zebra mussels to infest the lake.

Attribute	Description	Infestation Risk
Water Connectivity	Flows from 5 uninfested lakes	Moderate
Distance from nearest upstream lake	126.6 miles	Low
Presence of aquatic vegetation/wetland conditions	Minimal	Moderate
Public Use	Fishing, paddle sports	Moderate
Habitat Suitability/Substrate	Muddy, cloudy water	Low

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	936.6	Unknown	Low
Maximum Flow (cfs)	9,640	Unknown	Low
Summer maximum temperature (C)	27.5 (398)	>32 C	High
Dissolved oxygen average (mg/L)	8.7 (396)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	165	420	55	>30
Hardness	Mg/L	308	382	57	100-280
Specific Conductance	uS/cm	529	1,600	403	>110
Total Suspended Solids*	mg/L	120	1,900	403	<96
Turbidity*	NTU	82	1,938	592	<80

**possible limiting parameter for streams*

Results and Analysis

Results

The lakes in the Wild Rice River Watershed resulted in differing infestation and suitability risk ratings (Table 13). In general terms, the headwaters lakes came out with the lowest infestation risk ratings because they have no water bodies upstream. The headwaters lakes in the Wild Rice River Watershed include Upper and Lower Rice Lakes. Lakes that had moderate infestation risk ratings were White Earth, South and North Twin Lakes. These lakes came out as moderate because of the public use and residential development (Figure 13).

No lakes in the Wild Rice River Watershed scored high for infestation risk. This is mainly because many of the lakes do not have other lakes flowing into them, and compared to the Detroit Lakes area they have lower public use.

White Earth and South Twin Lake in the Wild Rice River Watershed resulted in a high Zebra mussel suitability rating (Figure 17). The lakes in northwest Minnesota are considered hardwater lakes from glacial deposits of calcium carbonate (limestone) (Wetzel 2001). All of the lakes in this study had suitable water chemistry, including calcium, for Zebra mussel growth and development.

The limiting factor that resulted in some lakes receiving a moderate 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). Therefore, lakes that have predominantly silt, muck and sand have a low substrate suitability rating. These lakes also tend to be more eutrophic, and Zebra mussels do not thrive in eutrophic lakes like they do in mesotrophic lakes (Karatayev et al. 1998, Nelepa 1992). The lakes with moderate suitability ratings included Roy, North Twin, Upper Rice and Lower Rice Lakes (Table 13).

The Wild Rice River itself is a pathway 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. The headwaters reach of the Wild Rice River in Clearwater and Mahnomen Counties County is uninfested and remote, and therefore received a low infestation rating. The downstream reaches of the Wild Rice River are too far away from the lakes for them to be a source of Zebra mussels, so they received a low infestation rating as well.

White Earth and South Twin Lakes were determined to be at greatest risk in the watershed for infestation, and they are most suitable for Zebra mussels to thrive, which means they should be targeted for protection (Table 13).

Table 13. Summary of risk ratings and prioritized recommendations taking into account the risk.

Lake Name	Lake ID	Public Use Risk	Infestation Risk	Suitability Risk	Infestation Status as of 9/9/2014	AIS Program Prioritized Recommendations
White Earth	03-0328-00	Moderate	Moderate	High	No AIS	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
North Twin	44-0023-00	Moderate	Moderate	Moderate	No AIS	1. Education
South Twin	44-0014-00	Moderate	Moderate	High	No AIS	1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Roy	44-0001-00	Low	Low	Moderate	No AIS	1. Education
Upper Rice	15-0059-00	Low	Low	Moderate	No AIS	1. Education
Lower Rice	15-0130-00	Low	Low	Moderate	No AIS	1. Education
Wild Rice River: Headwaters		Moderate	Low	Low	No AIS	1. Education
Wild Rice River: Lower Rice Lake to Twin Lake Creek		Moderate	Low	Low	No AIS	1. Education
Twin Lake Creek		Moderate	Moderate	Low	No AIS	1. Education
Wild Rice River: Twin Lake Creek to White Earth River		Moderate	Low	Low	No AIS	1. Education
White Earth River		Moderate	Moderate	Low	No AIS	1. Education
Wild Rice River: White Earth River to Marsh Creek		Moderate	Low	Low	No AIS	1. Education
Marsh Creek		Moderate	Low	Low	No AIS	1. Education
Wild Rice River: Marsh Creek to South Branch		Moderate	Low	Low	No AIS	1. Education
South Branch Wild Rice River		Moderate	Low	Low	No AIS	1. Education
Wild Rice River: South Branch to Red River		Moderate	Low	Low	No AIS	1. Education

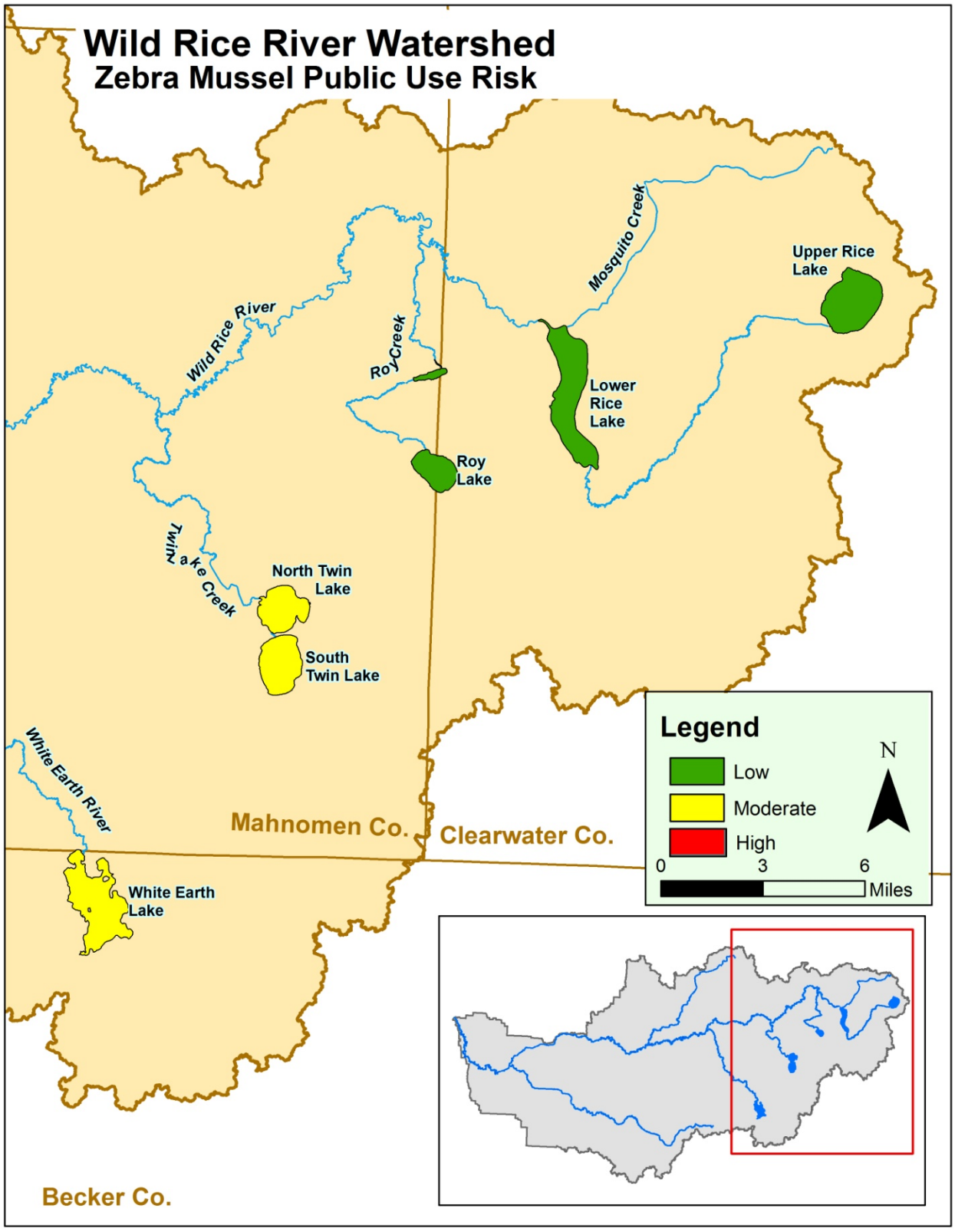


Figure 9. Public use risk ratings for Wild Rice River Lakes.

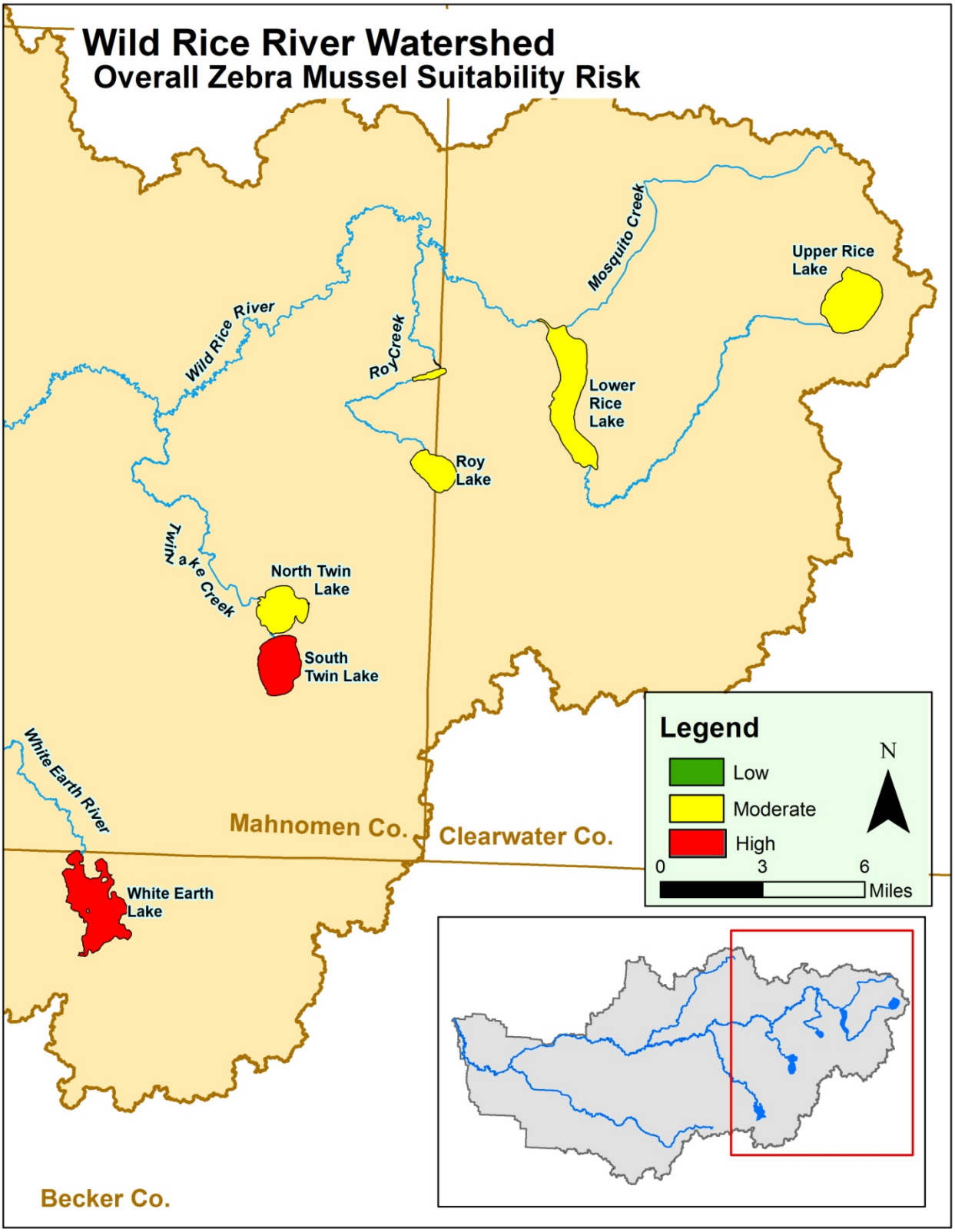


Figure 10. Lake suitability ratings to Zebra mussel survival.

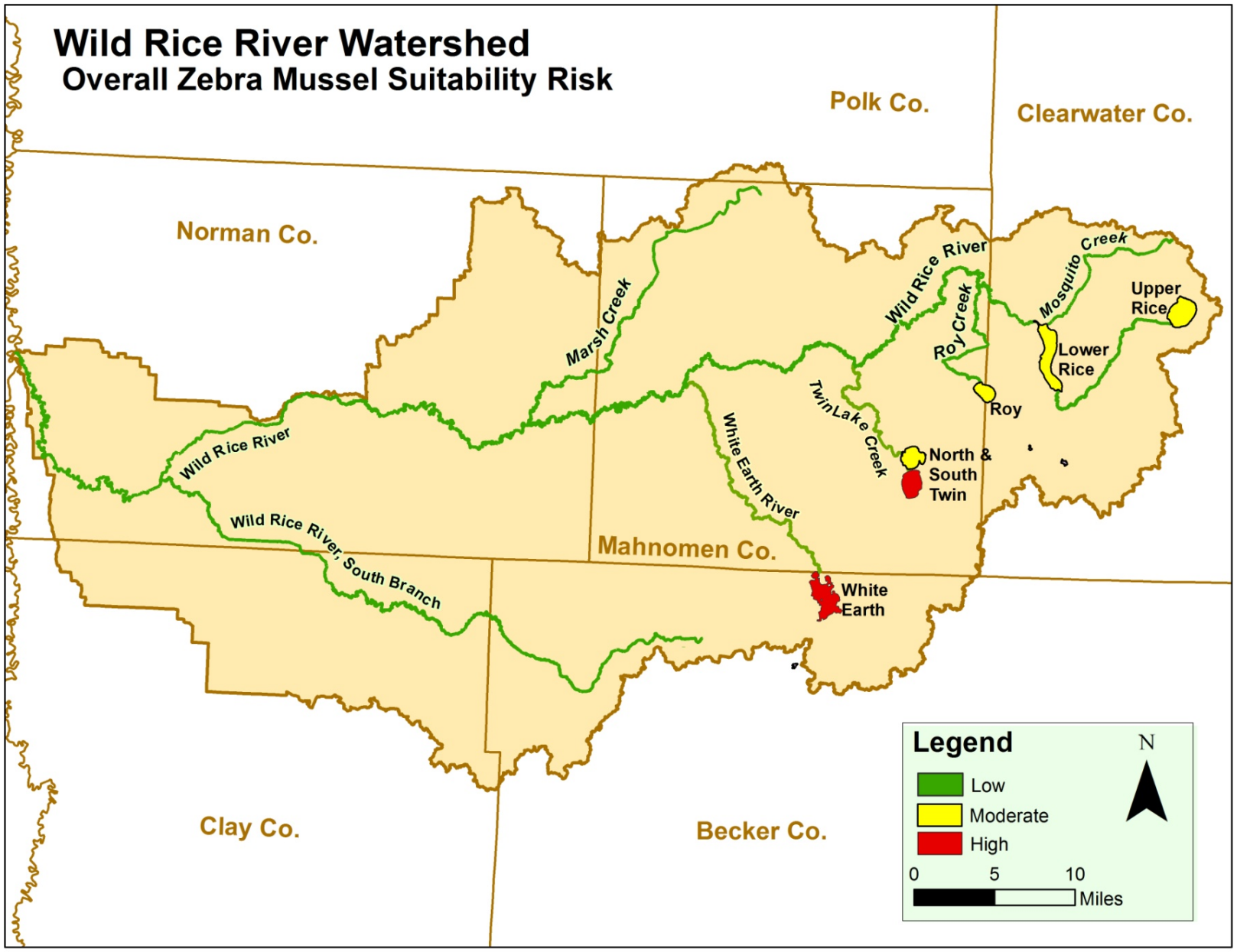


Figure 11. Lake and stream suitability ratings to Zebra mussel survival.

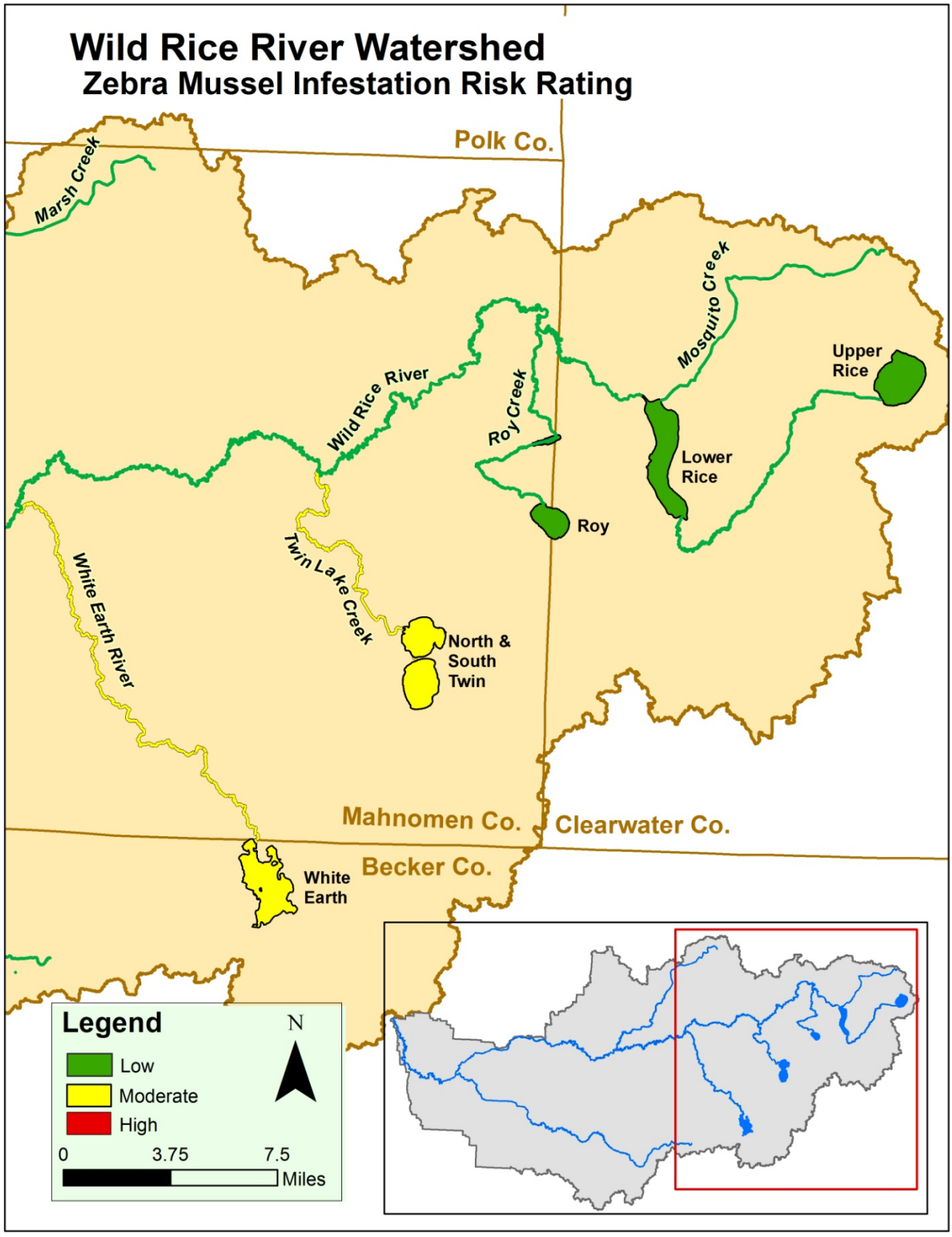


Figure 12. Zebra mussel infestation risk rating, eastern half of Wild Rice River Watershed.

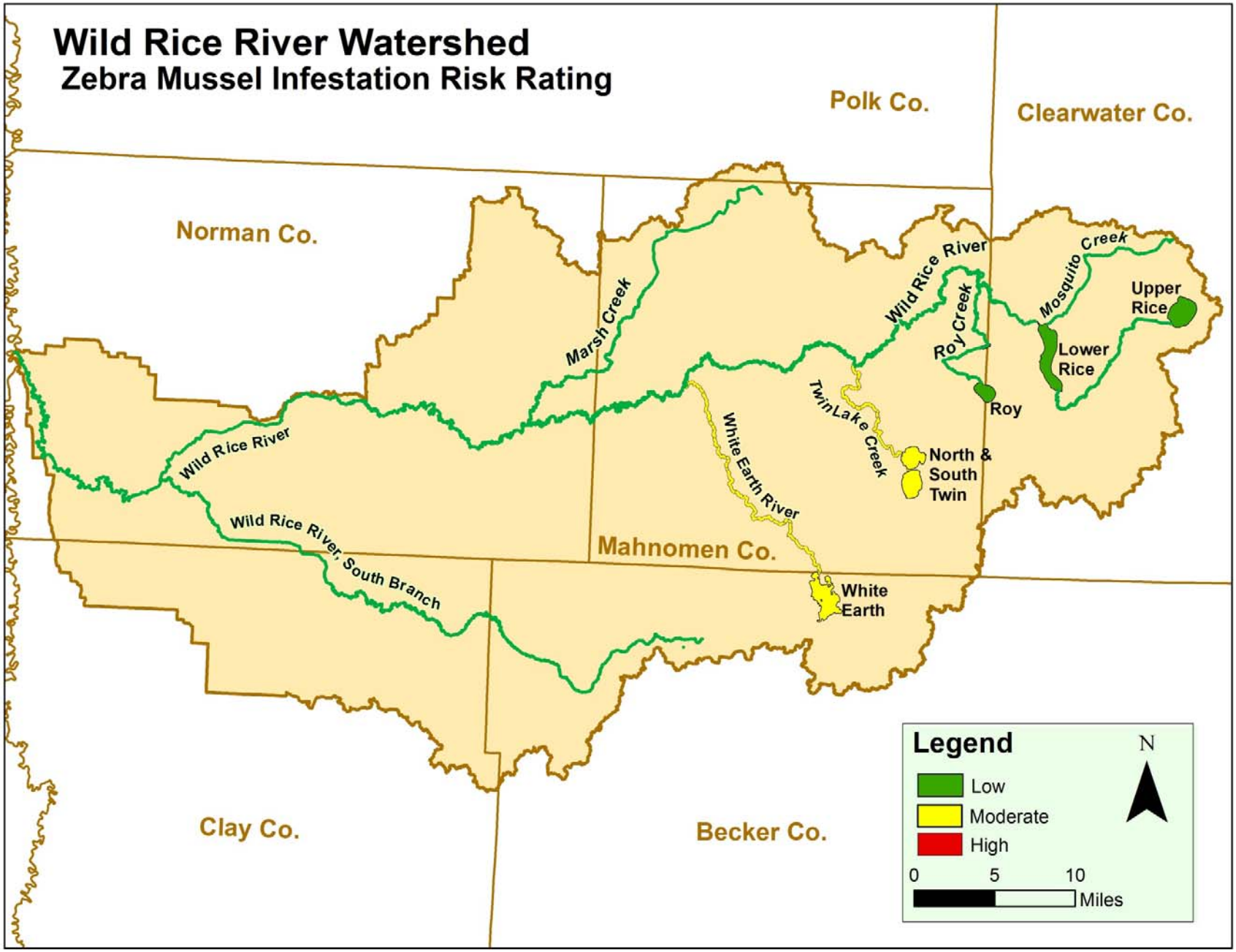


Figure 13. Zebra mussel infestation risk rating for the Wild Rice River Watershed lakes and rivers.

Data Gaps

This study identified some data gaps in the Wild Rice River Watershed. 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. The data gaps are indicated on the lake report cards. See the table below for a summary of parameters needed for each water body (Table 14).

Table 14. Summary of data gaps for water bodies in the Wild Rice River Watershed.

Waterbody Name	**Lake DOW**	**Parameters Needed**
White Earth	03-0328-00	Calcium, pH, Alkalinity, Conductivity
North Twin	44-0023-00	Calcium, Alkalinity, Conductivity
South Twin	44-0014-00	None (Tier 1 Sentinel Lake)
Roy	44-0001-00	Calcium
Upper Rice	15-0059-00	Calcium
Lower Rice	15-0130-00	Calcium, pH, Alkalinity, Conductivity, Secchi depth, Chlorophyll a, Total Phosphorus, Temperature, Dissolved Oxygen
Wild Rice River: Headwaters		Flow, Calcium, Hardness
Wild Rice River: Lower Rice Lake to Twin Lake Creek		Flow, Calcium, Hardness
Twin Lake Creek		Flow, Calcium, Hardness, Turbidity
Wild Rice River: Twin Lake Creek to White Earth River		Flow, Calcium, Hardness
White Earth River		Flow, Calcium, Hardness
Wild Rice River: White Earth River to Marsh Creek		None
Marsh Creek		Flow, Calcium, Hardness
Wild Rice River: Marsh Creek to South Branch		Flow
South Branch Wild Rice River		Flow, Calcium, Hardness
Wild Rice River: South Branch to Red River		None

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. Below are the pathways prioritized as to highest risk. 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 is shown in Table 13.

1. Connectivity via a river or stream.
   An upstream infested lake is a sure bet for infesting 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 no risk of veliger transfer in the winter* (Rufer 2014).

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 (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 14, 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 15, Rufer 2015).

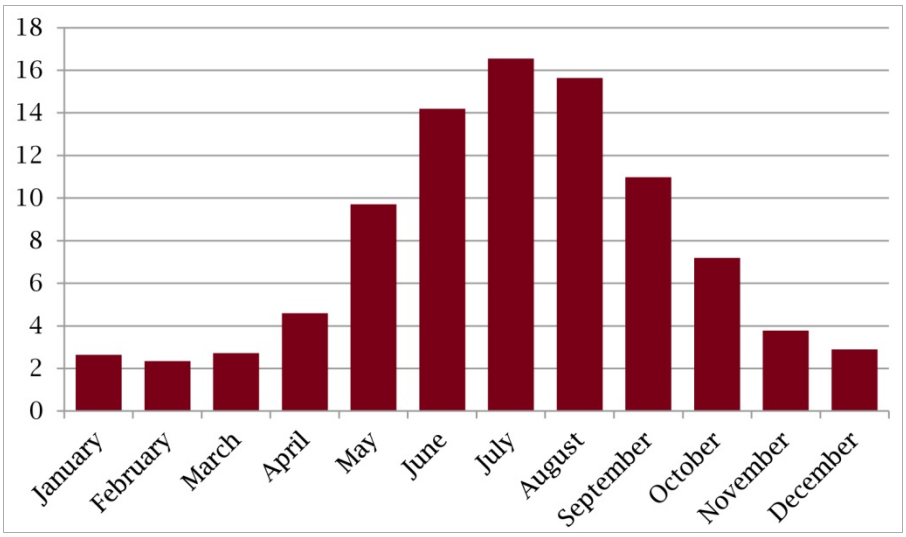


Figure 14. Average number of days occupied per month (n=552) from Pesch & Bussiere 2014.

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

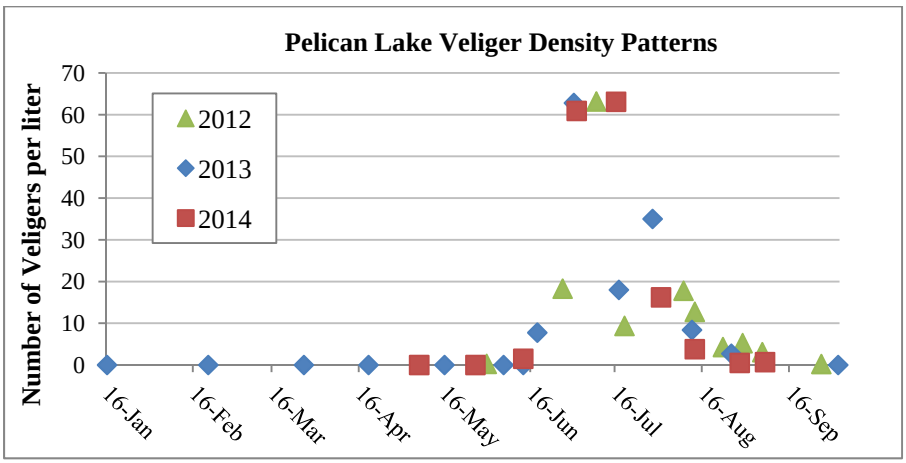


Figure 15. Veliger densities in Pelican Lake, 2012-2014 from Rufer 2015.

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

Table 15. 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

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 14). 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.

The assessments in this report result combine the report cards with the risk of time of year (Figure 15) in the following specific Aquatic Invasive Species Program Management Recommendations (Table 16). 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. 16. Framework for the watershed's AIS plan.

Activity	Target Lakes	Target Time of Year	Who	Cost	Narrative
Watercraft Inspections	Priority 1: • White Earth • South Twin Priority 2: • All	Priority 1: July Priority 2: August	County	TBD	This activity depends on available funding. If limited funding is available, focus inspections on White Earth and South Twin Lakes in July as the best use of funds.
Early Detection Monitoring: *Adult Zebra mussels*	Priority 1: • White Earth • South Twin Priority 2: All	Priority 1: September Priority 2: Every other week from late June to mid-September	Volunteers	$0	a. 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. b. In September, conduct a lake-wide inspection of docks and boat lifts as they are removed from the lake.
Early Detection Monitoring: *Zebra mussel veligers*	None, since no lakes rated as a high risk for infestation	July	County, Watershed District, or Lake Associations	$360	Collect plankton tow samples in early and late July for veliger analysis. Early detection allows for possible treatment.

Table 16 continued on the next page

Table. 16 continued. Framework for the watershed's AIS plan.

Activity	Target Lakes	Target Time of Year	Who	Cost	Narrative
Monitoring: Invasive Plants	Priority 1: • White Earth • South Twin Priority 2: • All	Mid to late June	County, Watershed District, or Lake Associations	TBD	Conduct plant surveys to look for aquatic invasive plants. Mid to late June will catch Curly-leaf pondweed, Flowering rush, and Eurasian watermilfoil. .
Water Quality Monitoring	See Table 14 for data gaps.	May – September	Lake Associations, watershed	TBD	Monitor lakes for missing parameters shown in Table 14. Priority parameters for each lake would be Calcium, Alkalinity, pH and Specific Conductance as they have the most effect on Zebra mussel suitability.
Education and Outreach	Priority 1: • White Earth • South Twin Priority 2: 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 resorts, focus *additional* education around 4th of July since that is the highest risk time of the year for spread.
Decontamination	None yet, as none have Zebra mussels yet	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.
Rapid Response Plan	All	Year round	County or watershed	TBD	Put together a plan of the chain of contacts if a new infestation is found and the steps to determine if treatment is possible. Having a plan in place allows for quick action if there is a new infestation.

Table 16 can be used as a framework for the best way to use available funding, as it shows when the priority time of year is and what the priority lakes are for each activity. For example, if funding is limited for watercraft inspections at public accesses, the funding should first be used to cover White Earth and South Twin lakes in July.

For early detection 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.

For education, 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 at resorts.

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