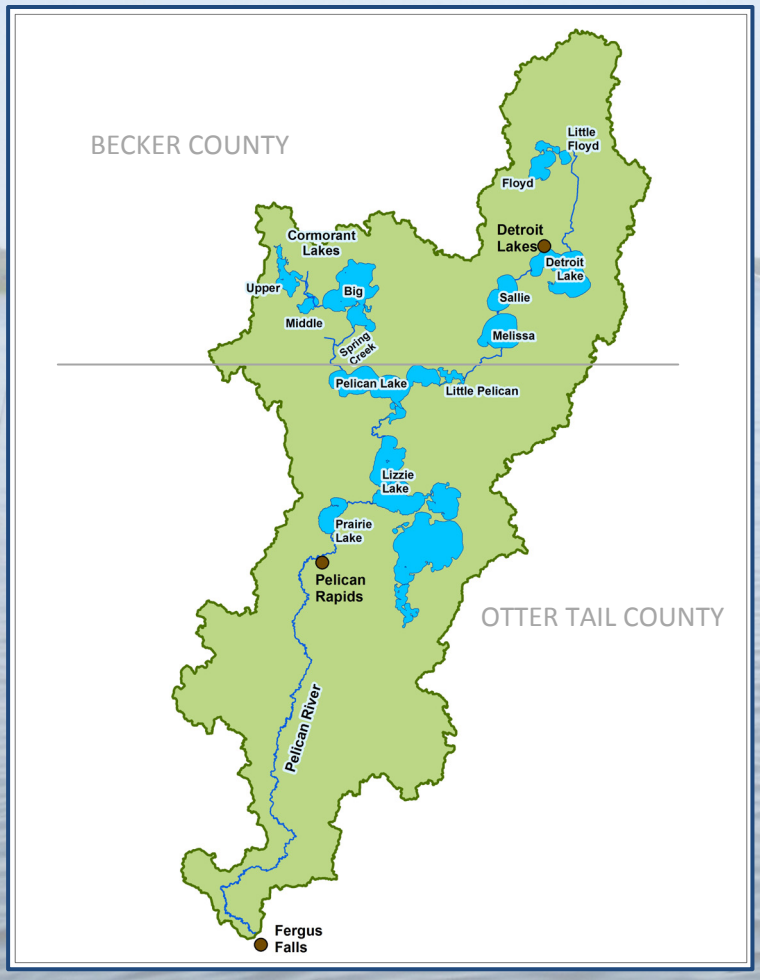
Pelican River Watershed

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.

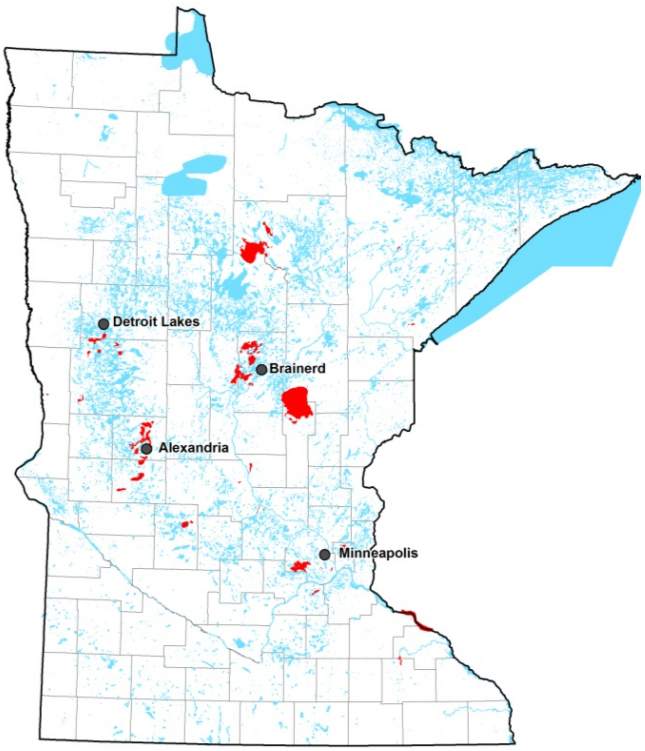


Figure 1. Minnesota Lakes infested by Zebra mussels, 2014.

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 2014, approximately 60 lakes in Minnesota were 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 Pelican 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 14). 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 Otter Tail, 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.

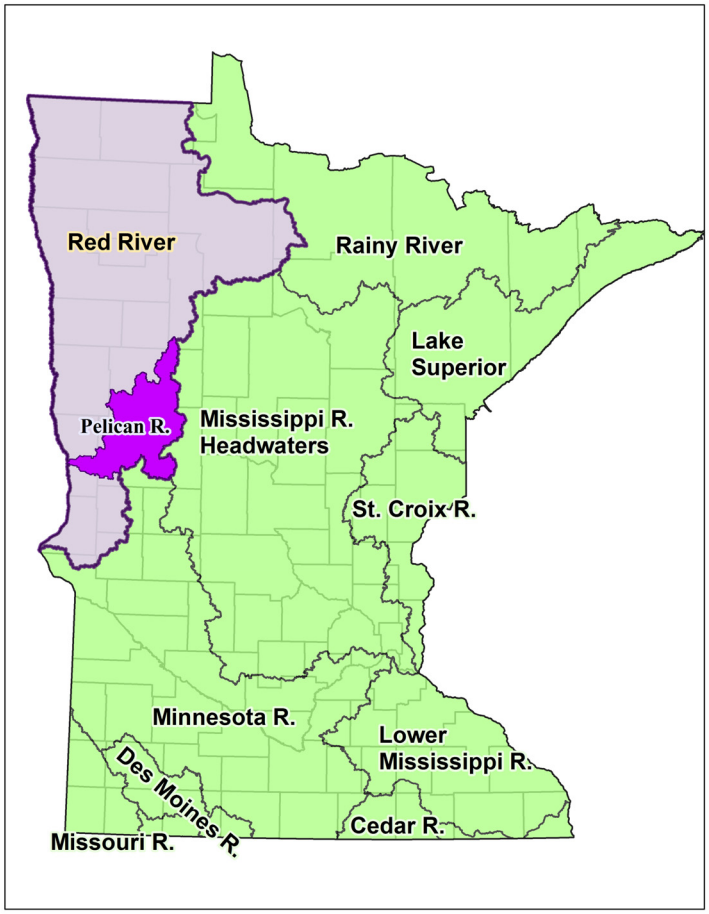


Figure 2. Minnesota showing all major drainage basins, the Red River Basin, and the Otter Tail River Watershed.

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 Otter Tail River Major Watershed represents an area of about 1,920 square miles, including areas of substantial portions of Otter Tail, Becker and Wilkin counties, and very small portions of Clay and Clearwater counties (Figure 3).

The Otter Tail River Watershed is a drainage basin of the Red River and the major tributaries of the watershed are the Ottertail and Pelican Rivers. Where the Otter Tail River joins the Bois de Sioux River is considered to be the headwaters of the Red River. The majority of the lakes in the Red River Basin are found in the Otter Tail River Watershed.

Pelican River Watershed

The Pelican River Watershed is a subset of the Otter Tail River Major Watershed (Figure 3). Its headwaters start north of Floyd Lake in Campbell Creek. From there it flows south through Floyd Lake, through the City of Detroit Lakes to Detroit, Sallie, Melissa, Pelican, Lizzie and Prairie Lakes. From Prairie Lake it flows south and joins the Otter Tail River near Fergus Falls.

There are two taxing entities in the Pelican River Watershed that have jurisdiction over the area. The Pelican River Watershed District encompasses the northern portion of the watershed through Lake Melissa. Pelican Lake has a Lake Improvement District, which encompasses Pelican, Bass, Fish and Little Pelican Lakes and includes all lakeshore properties.

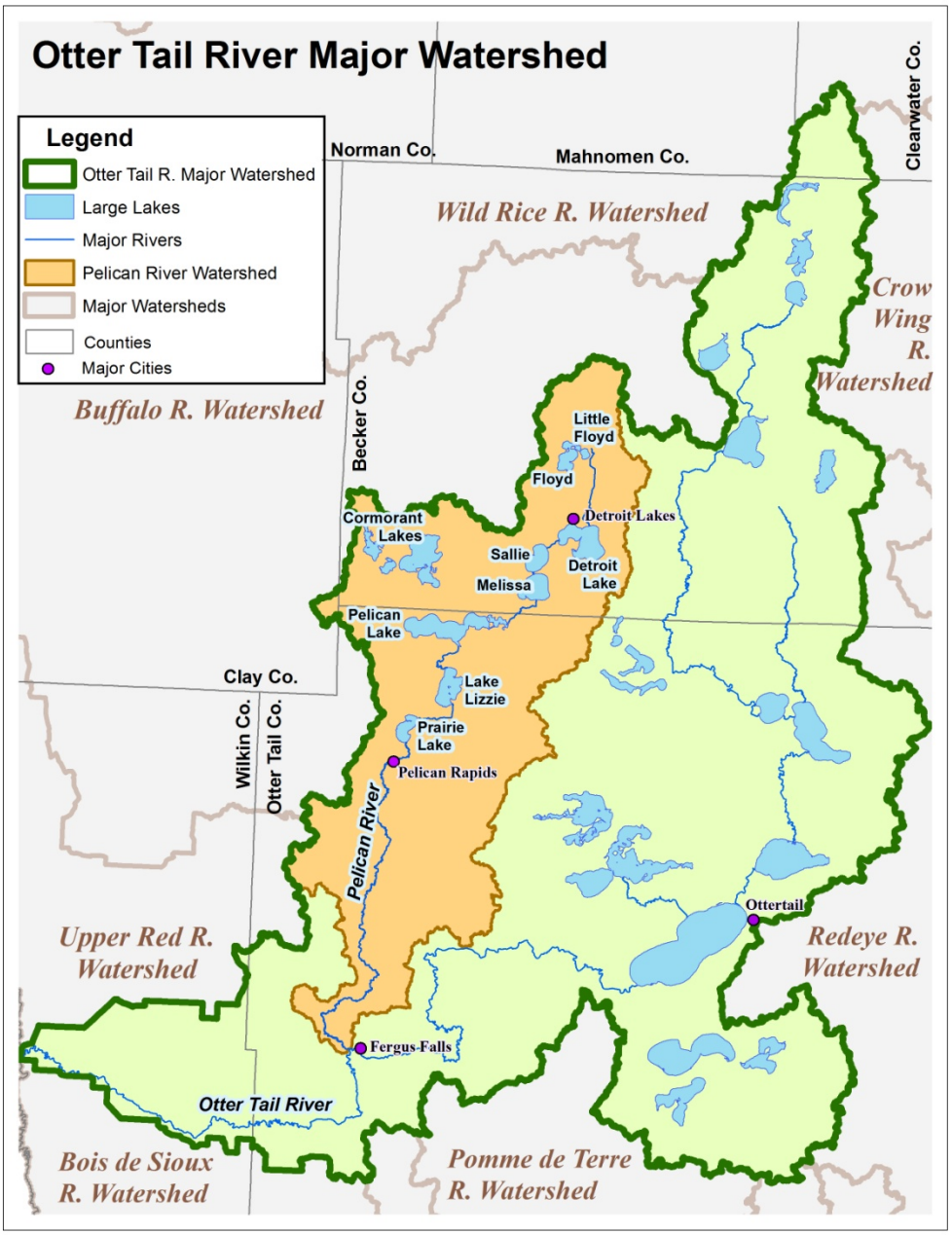


Figure 3. Otter Tail River Watershed and Pelican River Subwatershed with its lakes and rivers.

History of AIS in the Pelican River Watershed

Plants

The first aquatic invasive species (AIS) documented in the Pelican River Watershed was Flowering rush, an emergent plant (Figure 5). It is thought that it was purchased from a nursery and planted in Deadshot Bay intentionally due to its showy pink flowers.

Flowering Rush was first identified in Deadshot Bay in the mid-1970's and spread into the Big Detroit Lake by the end of that decade (Figure 4). By the early 1980's it was found in many places around Big and Little Detroit; and moved down the Pelican River to Muskrat, Sallie and Melissa.

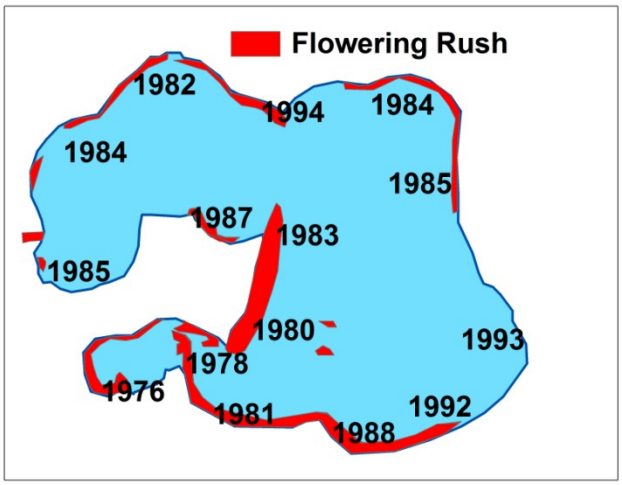


Figure 4. Map of Detroit Lake showing the spread of Flowering rush (prwd.org).

Flowering rush was mechanically harvested from 1967 to the mid 2000s in an effort to keep it under control. In the 2000s the Pelican River Watershed District (PRWD) began chemical herbicide treatment. Initial herbicide treatments were not deemed successful, so in 2010 PRWD adopted a ten-year plan to research effective ways to control Flowering rush. This research has proved successful, and the herbicide *Diquot* has significantly reduced Flowering rush in Detroit, Sallie and Melissa Lakes in the past couple years.

Curly-leaf pondweed is also a common invasive plant in the Pelican River Watershed (Figure 6). 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 2013, Curly-leaf has been found in Detroit, Sallie, Melissa, Upper Cormorant, Middle Cormorant and Pelican Lakes (Figure 7). It is possible that it exists in other lakes as well and is just not documented.


Figure 5. A Flowering rush plant showing its pink flower and emergent reed-like vegetation.


Figure 6. Curly-leaf pondweed turion (wintering bud) (left), and young Curly-leaf pondweed plant beginning to curl (right).

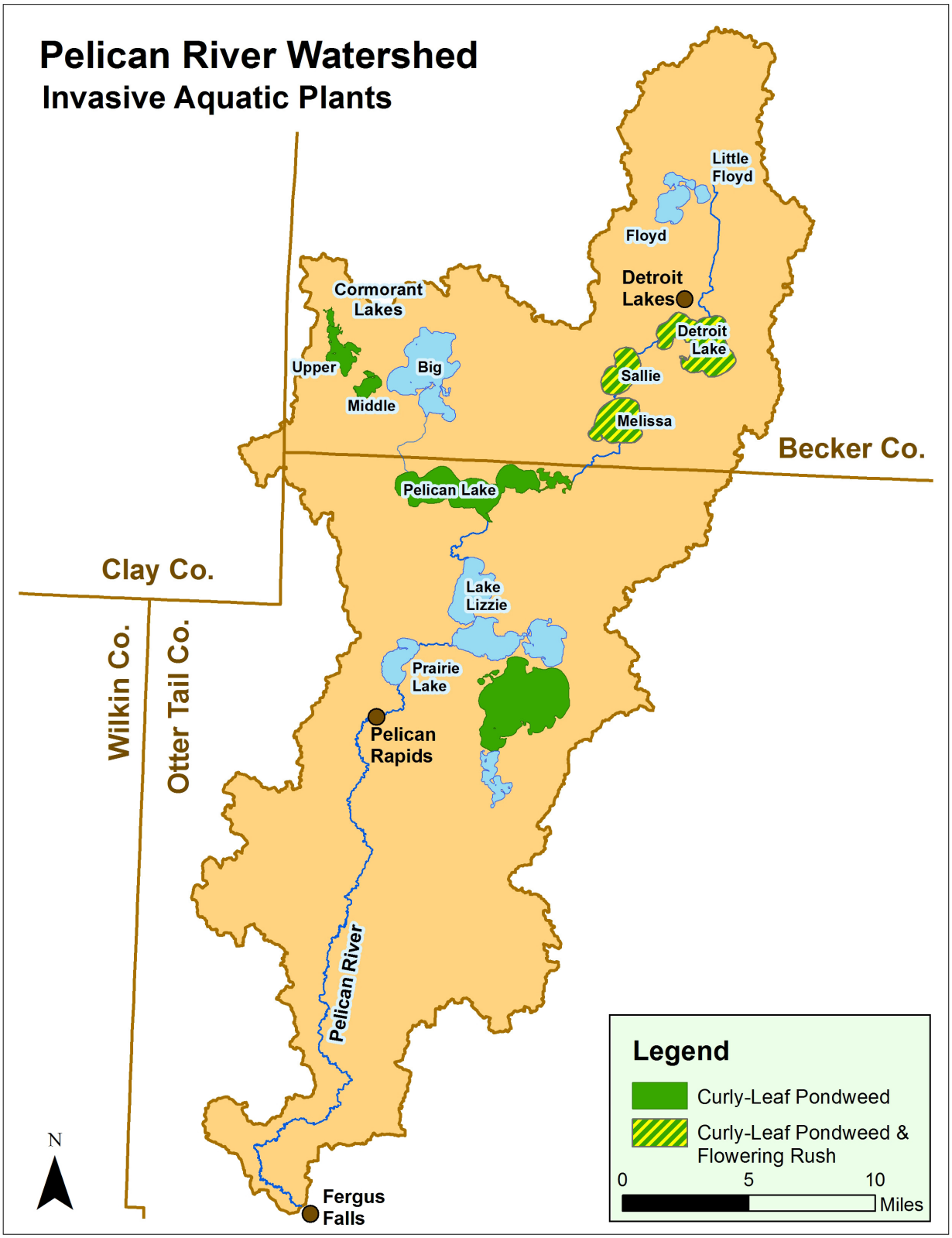


Figure 7. Aquatic plant infestations in the Pelican River Watershed.

Zebra mussels

Zebra mussels were first discovered in the Pelican River Watershed in Pelican Lake. A property owner found them in September of 2009 and the MNDNR confirmed their establishment after a survey that same day. In that survey, larger Zebra mussels were found (1/2-3/4 inches long), which could mean that the mussels had already been there for a year.

Figure 8. Zebra mussels on a sampling plate in Pelican Lake, 2013.

After confirmation in Pelican Lake, the MNDNR looked for Zebra mussels in Lake Lizzie, the next lake downstream. They found a few small Zebra mussels attached to boat lifts at this time. The Zebra mussels in Lake Lizzie could have come down the Pelican River from Pelican Lake; or it could have been an independent infestation. Downstream dispersal is discussed in further detail on page 18 of this report.

In 2011, Zebra mussels were found in Prairie Lake. Again, it is possible that these mussels came downstream from Lake Lizzie, but it also could have been an independent infestation. It was approximately two years between the infestation in Lizzie and Prairie Lakes. (Figure 9).

In 2012, Zebra mussels were found in the Otter Tail River after it's confluence with the Pelican River. From Orwell Reservoir, they have spread into Wilkin County (Figure 10). In 2013, they were found in Lake Lida (Figure 9).

As of 2013, Zebra mussels had only been found downstream from Pelican Lake. This means that for five years after the Pelican Lake infestation, no lakes in Becker County were infested. As of 2014, this changed and zebra mussels were found in Lake Melissa, which is upstream of Pelican Lake. This upstream spread was most likely due to lake users (Figure 9).

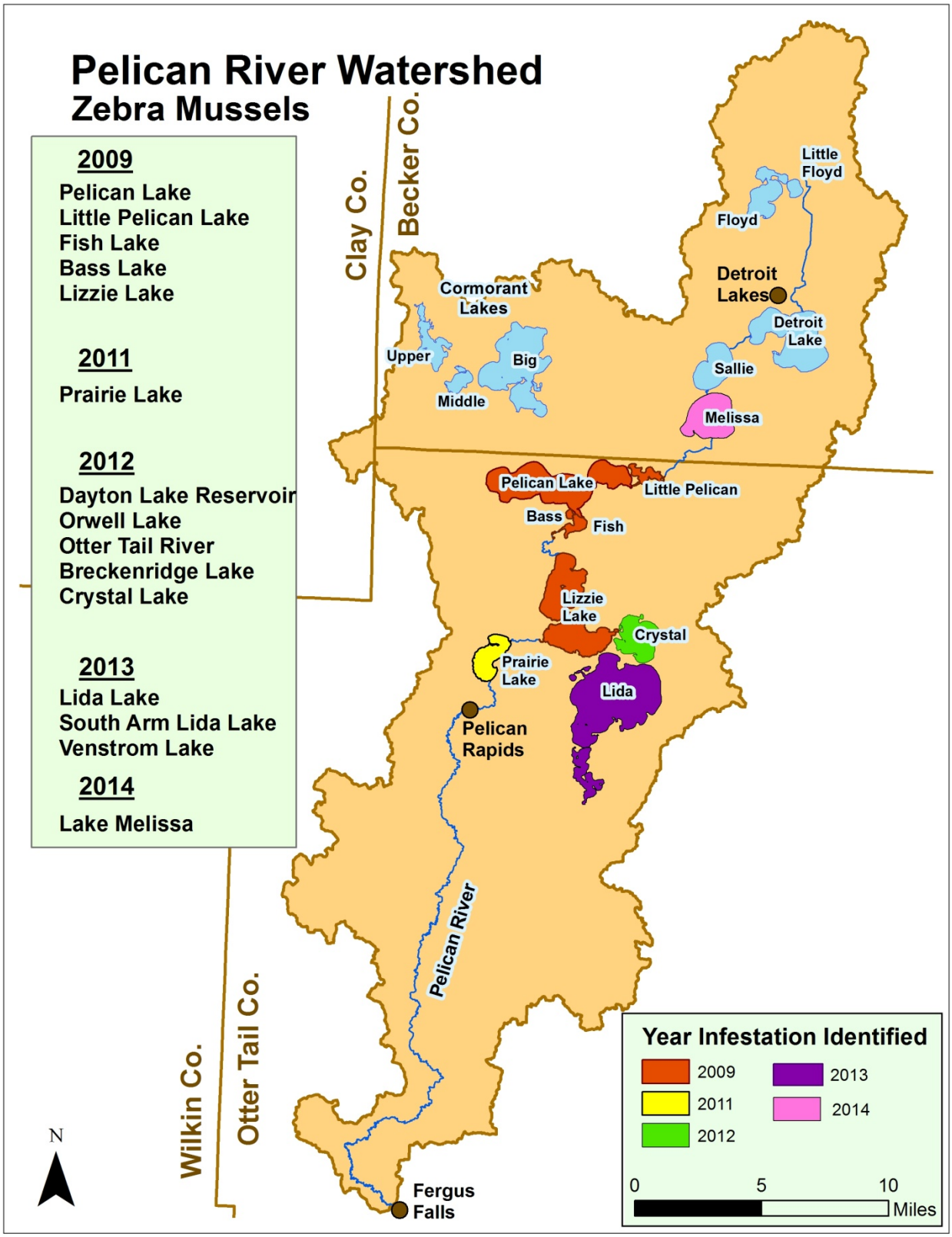


Figure 9. The spread of Zebra mussels in the Pelican River Watershed from 2009-2013.

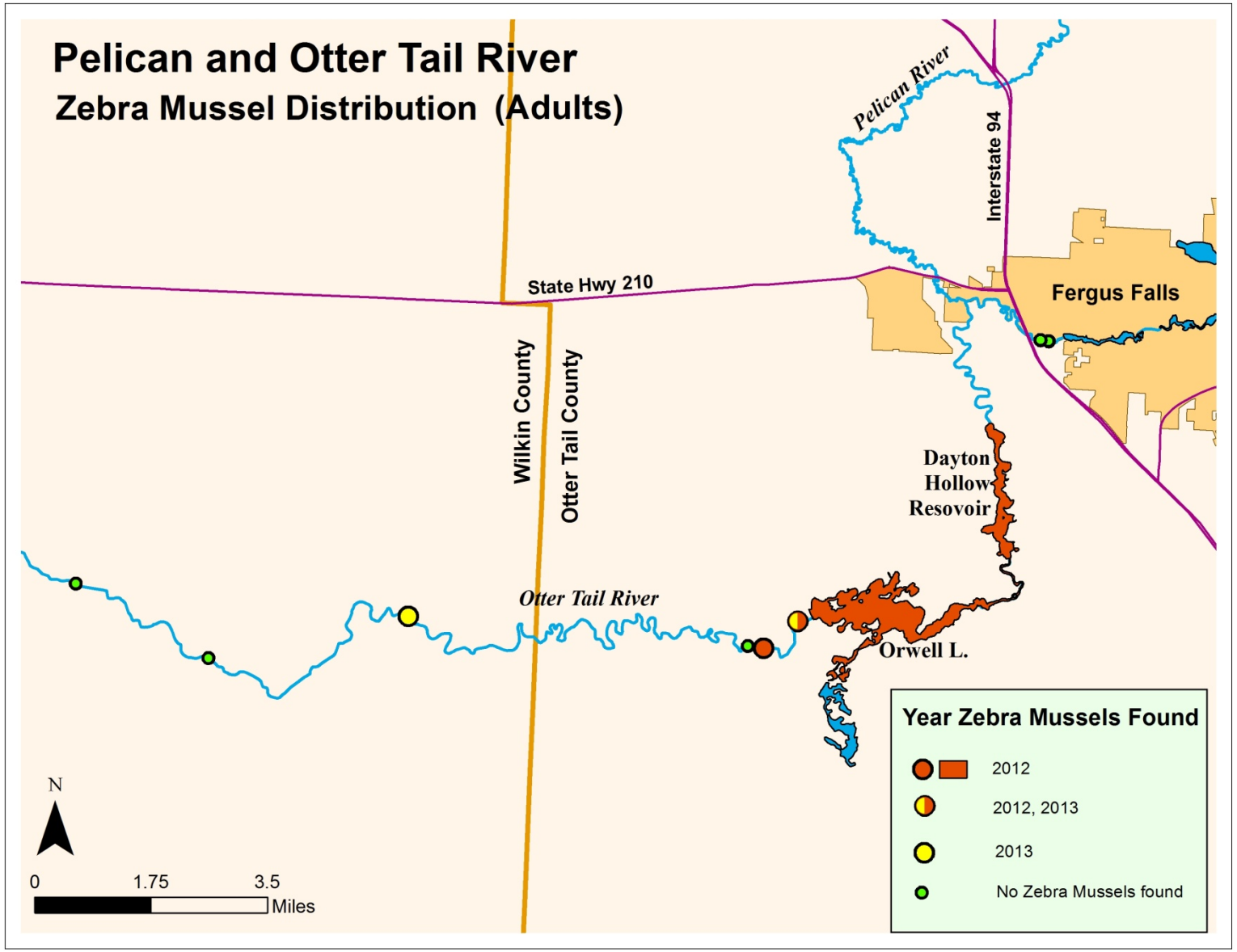


Figure 10. The spread of zebra mussel adults in the Otter Tail River.

Zebra Mussel Risk Assessment

Lake Methods

All the major lakes in the Pelican River Watershed have water chemistry, temperature, and dissolved oxygen data available (Table 1). These data were collected by the Pelican River Watershed District, Lake Associations, and the Pelican Group of Lakes Improvement District, and were used in the Zebra mussel risk assessment for lakes.

Table 1. Major lakes in the Pelican River Watershed.

Lake Name	Lake ID
Upper Cormorant	03-0588-00
Middle Cormorant	03-0602-00
Big Cormorant	03-0576-00
Big Floyd	03-0387-02
Little Floyd	03-0386-00
Detroit	03-0381-00
Sallie	03-0359-00
Melissa	03-0475-00
Pelican	56-0786-00
Little Pelican	56-0761-00
Lizzie	56-0760-00
Prairie	56-0915-00

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. A lot of resorts and hotels

on the lake show that there are many visitors to the lake outside the immediate area, which poses more risk for 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 the 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
Pelican	999	600	4065	70	5,734	High
Big Cormorant	643	360	3930	70	5,003	High
Detroit	608	240	3330	40	4,218	High
Melissa	397	300	720	0	1,417	Moderate
Middle Corm	198	270	495	0	963	Moderate
Sallie	236	495	75	0	806	Moderate
Floyd	380	225	0	0	605	Low
Lizzie	337	165	0	0	502	Low
Upper Corm	233	150	150	0	533	Low
Little Floyd	111	120	180	0	411	Low
Prairie	138	36	0	0	174	Low
Little Pelican	120	0	0	0	120	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 Pelican 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
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 2014).

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 Methods

Water chemistry data have been collected throughout the Pelican River by the Pelican River Watershed District and the International Water Institute (Figures 12-13). For this assessment, the Pelican River was split into two sections: Becker County and Otter Tail County (Table 10, Figure 11).

Table 10. Pelican River and tributary sections in this report.

Section	Stream
1	Pelican River Becker County: Floyd Lake to Pelican Lake
2	Pelican River Otter Tail County: Pelican Lake to Fergus Falls

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 Pelican 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.

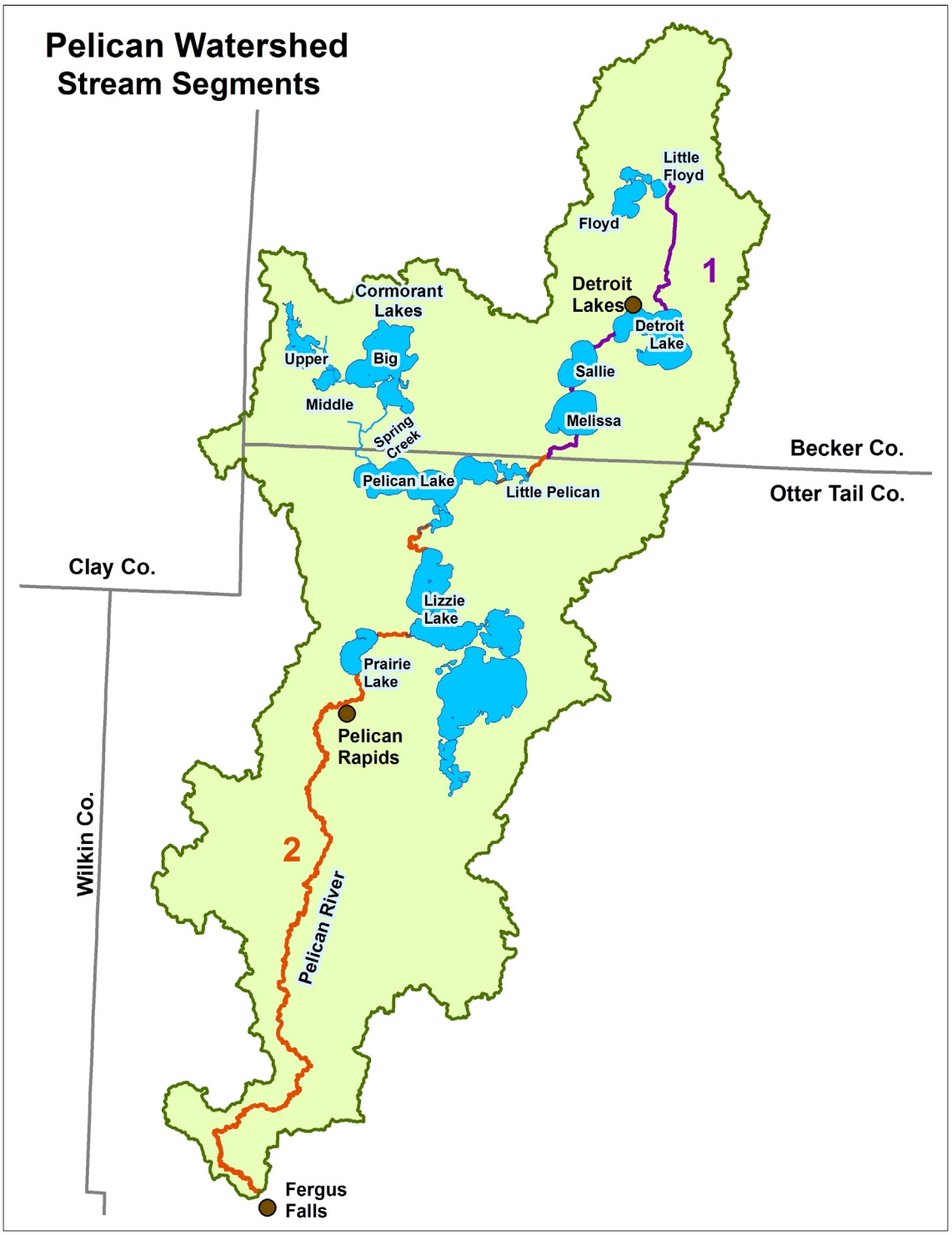


Figure 11. Pelican River stream segments used in this report.

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 Pelican River has 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 the risk assessment for the Pelican 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 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). 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.

Infestation Risk Rating
In the Pelican River Watershed, the lakes are fairly close in proximity to each other, and therefore the distance between lakes is possibly short enough to transport veligers to downstream lakes. 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 lake is the limiting factor for an infested stream. In streams, public use is secondary, and 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	Moderate	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 Pelican River. Results show that it is well below the threshold of 96 mg/L (Figures 12-13). Therefore, the total suspended solids are most likely not 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*

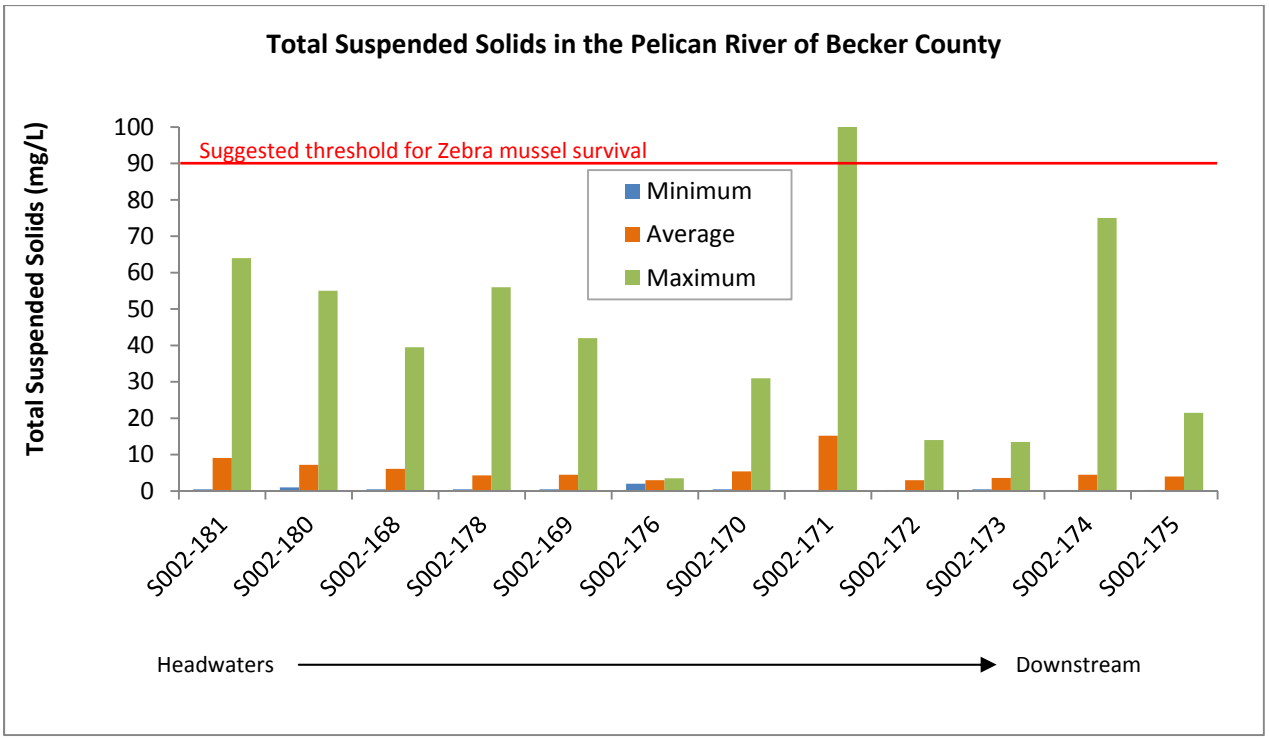


Figure 12. Total suspended solids results in the Pelican River of Becker County. Refer to site locations in Figure 12.

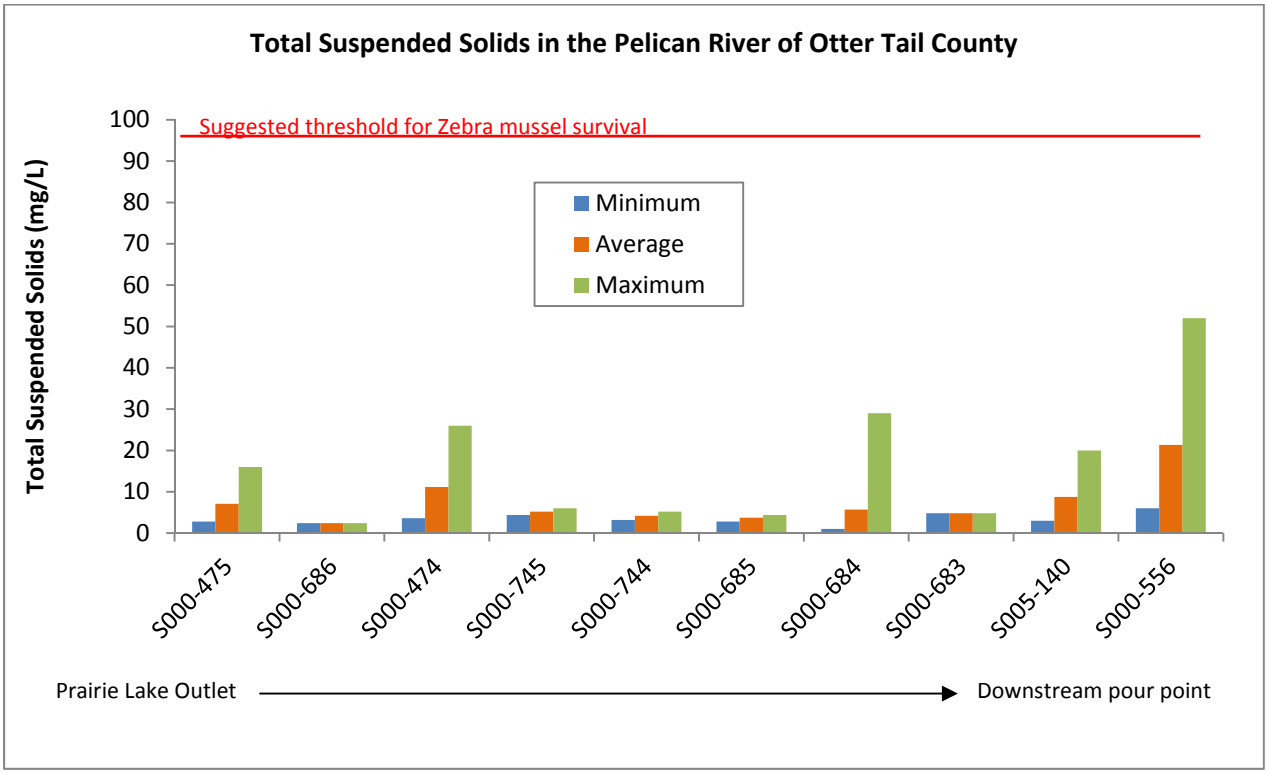


Figure 13. Total suspended solids results in the Pelican River of Otter Tail County. Refer to site locations in Figure 13.

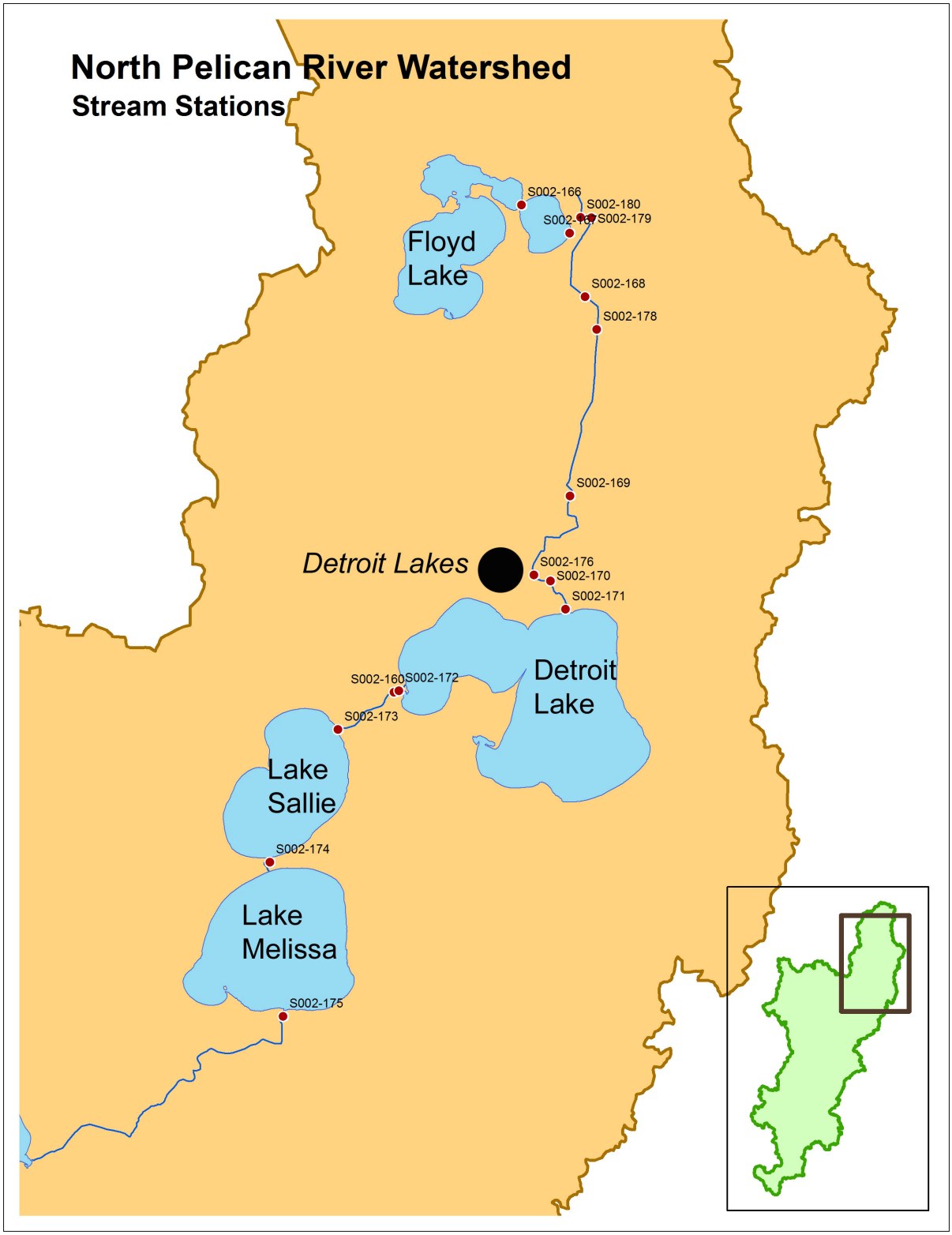


Figure 14. Stream monitoring sites in the Becker County portion of the Pelican River.

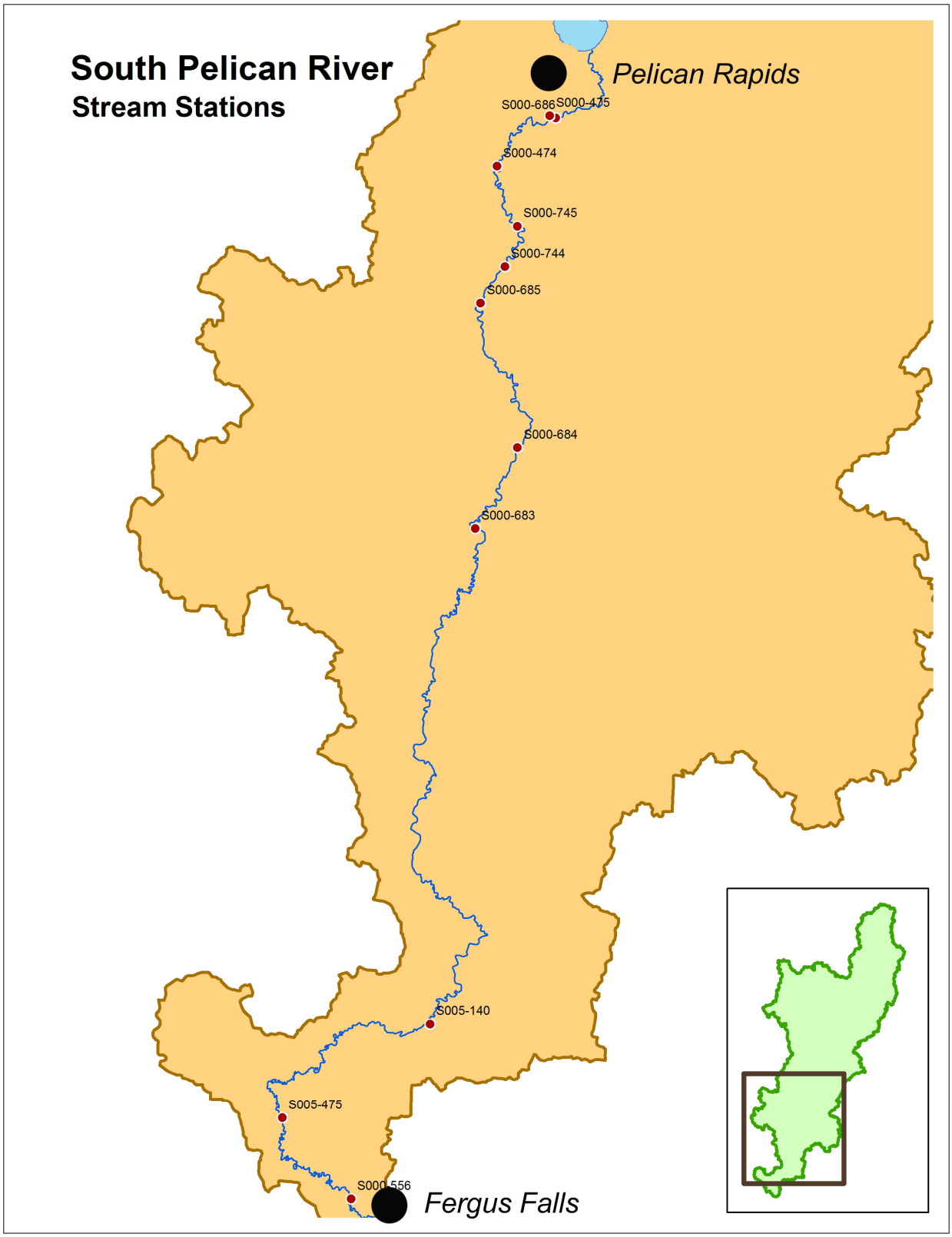


Figure 15. Pelican River stream sites in Otter Tail County.

Lake Risk Assessment Summary: Floyd 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 Basin: Otter Tail
Location: North of Detroit Lakes
Surface Area: 1,177 acres
Percent Littoral: 73%
Max Depth: 34 ft
Inlet: Campbell Creek

Summary

The only probable vector of spread for Floyd Lake is by humans and their boats/equipment since it is a headwaters lake. If Zebra mussels were introduced into Floyd Lake they would likely infest the lake, but may not thrive in large numbers due to the lack of hard substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (380)	605	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (225)		
Substrate Suitability (mean abundance, DNR)		Sand, Silt	56.3%, 33.3%	Low

Water Chemistry Risk

Parameter	Unit	Average	Sample Size	Suitable Range
Calcium*	Mg/L	NA	0	>30
pH*		8.6	63	8.2-8.8
Alkalinity*	mg/L	197	8	100-280
Conductivity*	uS/cm	380	53	>110
Secchi Depth	ft	9.6	82	6.56-13.12
Chlorophyll a	ug/L	3.8	19	2.5-8
Total Phosphorus	ug/L	17.6	35	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk

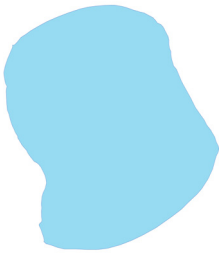
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 C (218 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Little Floyd 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 Basin: Otter Tail
Location: North of Detroit Lakes
Surface Area: 214 acres
Percent Littoral: 44%
Max Depth: 34 ft
Inlet: Pelican River



Summary

The only probable vector of spread for Little Floyd Lake is by humans and their boats/equipment since its only upstream lake is Floyd Lake (a headwaters lake.) If Zebra mussels were introduced into Little Floyd Lake they would likely infest the lake, but may not thrive in large numbers due to the lack of hard substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	One upstream headwaters lake	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (111)	411	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (300)		
Substrate Suitability (mean abundance, DNR)		Sand, silt, muck	45%, 32 %, 27%	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Count	Suitable Range
Calcium*	mg/L	NA	0	>30
pH*		8.3	471	8.2-8.8
Alkalinity*	mg/L	NA	0	100-280
Conductivity	umhos	407.1	394	>110
Secchi Depth	ft	8.6	306	6.56-13.12
Chlorophyll a	ug/L	8.8	94	2.5-8
Total Phosphorus	ug/L	29.2	255	25-35

**primary parameters for zebra mussel Suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

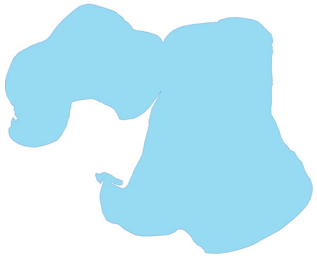
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28.9 °C (316 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Detroit Lake

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

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

Characteristics
Major Basin: Otter Tail
Location: Detroit Lakes
Surface Area: 3,067 acres
Percent Littoral: 62%
Max Depth: 89 ft
Inlet: Pelican River



Summary

Detroit Lake has a low probability of infestation from upstream since there is only one main lake upstream, and no current Zebra mussel infestations upstream of the lake. Due to its location within the City of Detroit Lakes, the lake has very high public use, which is high risk. If Zebra mussels were introduced into Detroit Lake they would most likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	One upstream lake	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (608)	4,218	High
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (3610)		
Substrate Suitability (mean abundance, DNR)		Sand, gravel	47%, 13%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.1	737	8.2 - 8.8
Alkalinity*	mg/L	186.4	14	100 - 280
Conductivity*	uS/cm	410.4	587	>110
Secchi	ft	10.2	355	6.56-13.12
Chlorophyll a	ug/L	8.3	41	2.5 - 8
Total Phosphorus	ug/L	25.4	43	25 - 35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk

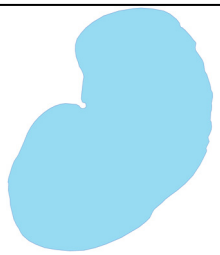
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 C (309 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Lake Sallie

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

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

Characteristics
Major Basin: Ottertail
Location: South of Detroit Lakes
Surface Area: 1272.88 acres
Percent Littoral: 45%
Max Depth: 50 ft
Inlet: Pelican River



Summary

Lake Sallie is in the middle of a chain of lakes, which is a moderate infestation risk. If any upstream lakes become infested, it will spread to Lake Sallie. Lake Melissa, which is immediately downstream from Lake Sallie is infested. If Zebra mussels were introduced into Lake Sallie they would most likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	1 immediate downstream infested lake	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (236)	806	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (570)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel	80%, 14%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.4	486	8.2-8.8
Alakalinity*	mg/L	190.0	5	100-280
Conductivity*	uS/cm	413.5	437	>110
Secchi Depth	ft	7.5	411	6.56-13.12
Chlorophyll a	ug/L	18.3	88	2.5-8
Total Phosphorus	ug/L	37.0	346	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27.7 °C (287 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Lake Melissa

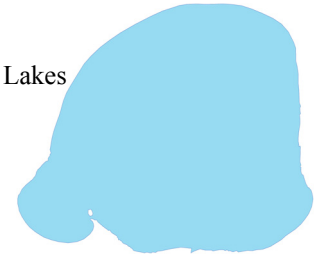
Overall Risk Rating: Moderate

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

Suitability Risk Rating: High

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

Characteristics
Major Basin: Ottertail
Location: South of Detroit Lakes
Surface Area: 1,850 acres
Percent Littoral: 51%
Max Depth: 37 ft
Inlet: Pelican River



Summary

Lake Melissa is currently infested with Zebra mussels. Due to suitable water chemistry and substrate, Zebra mussels are likely to thrive in Lake Melissa.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	4 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (397)	1,417	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (1,020)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel	82%, 10%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.5	304	8.2-8.8
Alkalinity*	mg/L	200	1	100-280
Conductivity*	uS/cm	392.8	271	>110
Secchi Depth	ft	8.8	246	6.56-13.12
Chlorophyll a	ug/L	11.3	11	2.5-8
Total Phosphorus	ug/L	23.0	18	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	29.3 °C (357 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Upper Cormorant

Overall 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 Basin: Ottertail
Location: West of Detroit Lakes
Surface Area: 926.83 acres
Percent Littoral: 51%
Max Depth: 29 ft
Inlet: From Bijou Lake

Summary

The only probable vector of spread for Upper Cormorant Lake is by humans and their boats/equipment since it is a headwaters lake. If Zebra mussels were introduced into Upper Cormorant Lake they would likely infest the lake, but may not thrive in large numbers due to the lack of hard substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Headwaters	0 upstream lakes	Low
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (233)	533	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (300)		
Substrate Suitability (mean abundance)		Sand, silt, muck	25%, 39%, 35%	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		NA	0	8.2-8.8
Alakalinity*	mg/L	NA	0	100-280
Conductivity*	uS/cm	NA	0	>110
Secchi	ft	7.4	91	6.56-13.12
Chlorophyll a	ug/L	13.4	44	2.5-8
Total Phosphorus	ug/L	31.1	44	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28.4 °C (19 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Middle Cormorant

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

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

Characteristics
Major Basin: Ottertail
Location: West of Detroit Lakes
Surface Area: 408.72 acres
Percent Littoral: 35%
Max Depth: 40 ft
Inlet: Upper Cormorant Lake

Summary

Middle Cormorant Lake is in the middle of a chain of lakes, which is a moderate infestation risk. If any upstream lakes become infested, it will spread to Middle Cormorant Lake. If Zebra mussels were introduced into Middle Cormorant Lake they would most likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Uninfested Chain of Lakes	3 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (198)	963	Moderate
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (765)		
Substrate Suitability (mean abundance, DNR)		Sand, gravel	73%, 42%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.9	4	8.2-8.8
Alkalinity*	mg/L	194	5	100-280
Conductivity*	uS/cm	342	5	>110
Secchi Depth	ft	11.4	416	6.56-13.12
Chlorophyll a	ug/L	5	17	2.5-8
Total Phosphorus	ug/L	16.2	17	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	28 °C (15 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Big Cormorant

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

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

Characteristics
Major Basin: Ottertail
Location: West of Detroit Lakes
Surface Area: 3657.06 acres
Percent Littoral: 22%
Max Depth: 75 ft
Inlet: Middle Cormorant Lake

Summary

Big Cormorant Lake has a moderate probability of infestation from upstream since it is in a chain of lakes. Due to its location and size, the lake has very high public use, which is high risk. If Zebra mussels were introduced into Big Cormorant Lake they would most likely thrive due to suitable water chemistry and substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Uninfested Chain of Lakes	4 upstream lakes	Moderate
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (643)	5,003	High
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (4,360)		
Substrate Suitability (mean abundance, DNR)		Sand, Rubble, Gravel	55%, 30%, 33%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Range for Zebra Mussels
Calcium*	mg/L	NA	0	>30
pH*		8.7	10	8.2-8.8
Alkalinity*	mg/L	250	11	100-280
Conductivity*	uS/cm	460	8	>110
Secchi	ft	18.9	178	6.56-13.12
Chlorophyll a	ug/L	4.0	78	2.5-8
Total Phosphorus	ug/L	25.2	89	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.9 °C (23 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Pelican Lake

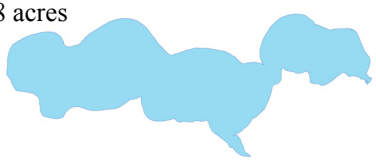
Overall Risk Rating: INFESTED

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

Suitability Risk Rating: High

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

Characteristics
Major Basin: Ottertail
Location: South of Detroit Lakes
Surface Area: 3962.88 acres
Percent Littoral: 41%
Max Depth: 55 ft
Inlet: Pelican River



Summary

Pelican Lake is currently an infested lake (listed in 2009). Its substrate and water chemistry is suitable for Zebra mussel establishment and growth.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of infested lakes	2 infested lakes upstream	High
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (999)	5,734	High
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (4,735)		
Substrate Suitability (mean abundance, DNR)		Sand, Gravel	78.8%, 18.3%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	35	55	>30
pH*		8.4	75	8.2-8.8
Alkalinity*	mg/L	192.5	12	100-280
Conductivity *	uS/cm	394.8	75	>110
Secchi	ft	12.8	192	6.56-13.12
Chlorophyll a	ug/L	4.8	116	2.5-8
Total Phosphorus	ug/L	14.6	116	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

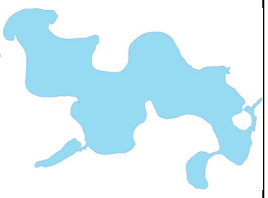
	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.5 °C (37 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Little Pelican Lake

Overall Risk Rating: INFESTED
1. Connectivity: High Risk
2. Public Use: Low Risk

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

Characteristics
Major Basin: Ottertail
Location: South of Detroit Lakes
Surface Area: 345 acres
Percent Littoral: 74%
Max Depth: 25 ft
Inlet: Pelican River



Summary

Little Pelican is currently an infested lake due to its connection with Pelican Lake; however, very few Zebra mussels have been found. It has a moderate suitability rating due to its substrate and eutrophic status.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	Connected to infested lake	High
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (120)	120	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (0)		
Substrate Suitability (mean abundance)		Silt, Muck	NA	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	34	55	>30
pH*		NA	0	8.2-8.8
Alkalinity*	mg/L	180	10	100-280
Conductivity *	uS/cm	412	12	>110
Secchi Depth	ft	8.5	87	6.56-13.12
Chlorophyll a	ug/L	9.8	87	2.5-8
Total Phosphorus	ug/L	23.9	87	25-35

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	26.5 °C (38 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Lake Risk Assessment Summary: Lake Lizzie

Overall Risk Rating: INFESTED

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

Suitability Risk Rating: Moderate

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

Characteristics
Major Basin: Ottertail
Location: North of Pelican Rapids
Surface Area: 1,900acres
Percent Littoral: 43%
Max Depth: 66 ft
Inlet: Pelican River

Summary

Lake Lizzie is infested with Zebra mussels (listed in 2009). Its substrate and water chemistry is suitable for Zebra mussel establishment and growth.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	1 upstream infested lake	High
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (337)	502	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (165)		
Substrate Suitability (mean abundance)		Sand, Rubble, Gravel	42%, 33%, 25%	High

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.4	3	8.2-8.8
Alkalinity*	mg/L	193.3	3	100-280
Conductivity *	uS/cm	NA	0	>110
Secchi Depth	ft	12.7	61	6.56-13.12
Chlorophyll a	ug/L	5.3	62	2.5-8
Total Phosphorus	ug/L	16.1	62	25-35
Turbidity	mg/L	1.2	3	<96

**primary parameters for zebra mussel suitability*

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	25.6 °C (27 observations)	>32 C	High
Dissolved oxygen	Dimictic	<7 mg/L	High

Lake Risk Assessment Summary: Prairie Lake

Overall Risk Rating: INFESTED

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

Suitability Risk Rating: Moderate

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

Characteristics
Major Basin: Ottertail
Location: Pelican Rapids
Surface Area: 1,002 acres
Percent Littoral: 80%
Max Depth: 22 ft
Inlet: Pelican River

Summary

Prairie Lake is infested with Zebra mussels (listed in 2011). Its water chemistry is suitable for Zebra mussel establishment and growth, but spread may be limited by the substrate.

Attribute		Description	Number	Infestation Risk
Water Connectivity		Chain of lakes	3 upstream infested lakes	High
Public Use	Resident Watercraft/Boat Lift Impact	Number of parcels (138)	174	Low
	Non-resident Watercraft Impact	Total number of resort units, public access parking spots and special events for summer (36)		
Substrate Suitability (mean abundance)		Sand, Silt	72.1%, 15.4%	Low

Water Chemistry Risk Summary

Parameter	Unit	Average	Sample Size	Suitable Ranges
Calcium*	mg/L	NA	0	>30
pH*		8.5	1	8.2-8.8
Alkalinity*	mg/L	180	1	100-280
Conductivity*	uS/cm	380	1	>110
Secchi Depth	ft	9.8	44	6.56-13.12
Chlorophyll a	ug/L	5.8	43	2.5-8
Total Phosphorus	ug/L	20.6	44	25-35

Seasonal Temperature and Dissolved Oxygen Risk Summary

	Description	Lethal Limit	Suitability Rating
Summer maximum temperature	27.8 °C (27 observations)	>32 C	High
Dissolved oxygen	Polymictic	<7 mg/L	High

Stream Risk Assessment Summary: Pelican River, Becker County

Infestation Risk Rating: Moderate

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

Suitability Risk Rating: Low

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

Characteristics

Major Basin: Otter Tail

County: Becker

Location: Floyd Lake to Lake Melissa

Length: 20 miles

Summary

The Pelican River in Becker County is uninfested with Zebra mussels upstream from Lake Melissa. Due to its connectivity to lakes, it is at a high risk for infestation. 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 would be needed to continually introduce veligers to the stream.

Attribute	Description	Infestation Risk
Water Connectivity	Uninfested chain of lakes	Moderate
Distance from nearest upstream lake	<6 miles between lakes	High
Presence of aquatic vegetation/wetland conditions	Yes	Low
Public Use	Fishing, bait harvest, paddle sports	Moderate
Habitat Suitability	Sand, Gravel, Rocks	High

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	42 (2,016)	Unknown	Low
Maximum Flow (cfs)	153 (2,016)	Unknown	Low
Summer maximum temperature (C)	27.5 (108)	>32 C	High
Dissolved oxygen average (mg/L)	7.7 (114)	<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	NA	NA	0	>110
Total Suspended Solids	mg/L	5.7	2,054	2,068	<96
Turbidity	NTU	NA	NA	0	<80

Stream Risk Assessment Summary: Pelican River, Otter Tail County

Infestation Risk Rating: INFESTED

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

Suitability Risk Rating: Moderate

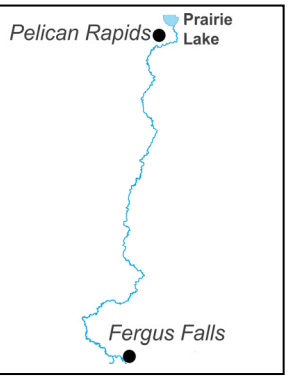
1. Flow Rate: Low Risk
2. Water Chemistry: High Risk
3. Temperature: High Risk
4. Dissolved Oxygen: High Risk

Characteristics

Major Basin: Otter Tail

Location: Pelican Lake to Otter Tail River (Pelican Rapids to Fergus Falls)

Length: 64 miles



Summary

The Pelican River is infested with Zebra mussels downstream from Pelican Lake to its pour point at the Otter Tail River near Fergus Falls, MN. The stream flow is likely the limiting factor for Zebra mussel survival within the stream itself, although there are many Zebra mussel source lakes along the stream that continually introduce veligers to the stream.

Attribute	Description	Infestation Risk
Water Connectivity	Infested	High
Distance from nearest upstream lake	64 miles	Low
Presence of aquatic vegetation/wetland conditions	Moderate	Moderate
Public Use	Fishing, bait harvest	Moderate
Habitat Suitability	Sand, Gravel, Rocks	High

Physical Parameters Risk

Item	Result (Sample Size)	Lethal Limit	Suitability Rating
Mean Flow* (cfs)	33 (6)	Unknown	Low
Maximum Flow (cfs)	83 (6)	Unknown	Low
Summer maximum temperature (C)	27.5 (108)	>32 C	High
Dissolved oxygen average (mg/L)	7.7 (114)	<7 mg/L	High

**possible limiting parameter for streams*

Water Chemistry Risk

Parameter	Unit	Average	Maximum	Sample Size	Suitable Range
Calcium	mg/L	102	139	10	>30
Hardness	Mg/L	244	284	10	100-280
Specific Conductance	uS/cm	410	470	83	>110
Total Suspended Solids	mg/L	10	52	80	<96
Turbidity	NTU	6	22	128	<80

Results and Discussion

Results

The lakes in the Pelican 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 Pelican River Watershed include Floyd, Little Floyd, and Upper Cormorant. Lakes that had moderate infestation risk ratings were Sallie, Melissa, and Middle Cormorant. These lakes came out as moderate because of the combination of moderate public use and being in the middle of a chain of lakes (Figure 17).

Lakes with high infestation risk ratings include Pelican, Big Cormorant and Detroit (Figure 17). These lakes are all part of chains of lakes, so have risk from connectivity. The highest risk to these three lakes; however, is their public use (Figure 16). They have the most resort units, public accesses, and property owners of any lakes in the watershed. Public use risks come from both lake visitors via boats and lake property owners via boats, boat lifts, docks and other water-related equipment. Pelican Lake was the first lake in the watershed to become infested with Zebra mussels, and it also had the highest public use rating of all the lakes in the watershed (Table 3).

Most of the lakes in the Pelican River Watershed resulted in a high Zebra mussel suitability rating (Figure 18). 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 Prairie, Little Pelican, Floyd, Little Floyd, and Upper Cormorant (Table 13).

The Pelican 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 northern half of the Pelican River in Becker County is uninfested, and therefore received a moderate infestation rating. The southern half of the Pelican River in Otter Tail County flows through infested lakes, and therefore received a high infestation rating.

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
Upper Cormorant	03-0588-00	Low	Low	Moderate		1. Education
Middle Cormorant	03-0602-00	Moderate	Moderate	High		1. Education
Big Cormorant	03-0576-00	High	High	High		1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Big Floyd	03-0387-02	Low	Low	Moderate		1. Education
Little Floyd	03-0386-00	Low	Low	Moderate		1. Education
Detroit	03-0381-00	High	High	High		1. Public Access Inspections 2. Education 3. Early Detection Monitoring
Sallie	03-0359-00	Moderate	Moderate	High		1. Education 2. Early Detection Monitoring
Melissa	03-0475-00	Moderate	High	High	Infested with Zebra mussels	1. Decontamination station 2. Education
Little Pelican	56-0761-00	Low	High	Moderate	Infested with Zebra mussels	1. Decontamination station 2. Education
Pelican	56-0786-00	High	High	High	Infested with Zebra mussels	1. Decontamination station 2. Education
Lizzie	56-0760-00	Low	High	High	Infested with Zebra mussels	1. Decontamination station 2. Education
Prairie	56-0915-00	Low	High	Moderate	Infested with Zebra mussels	1. Decontamination station 2. Education

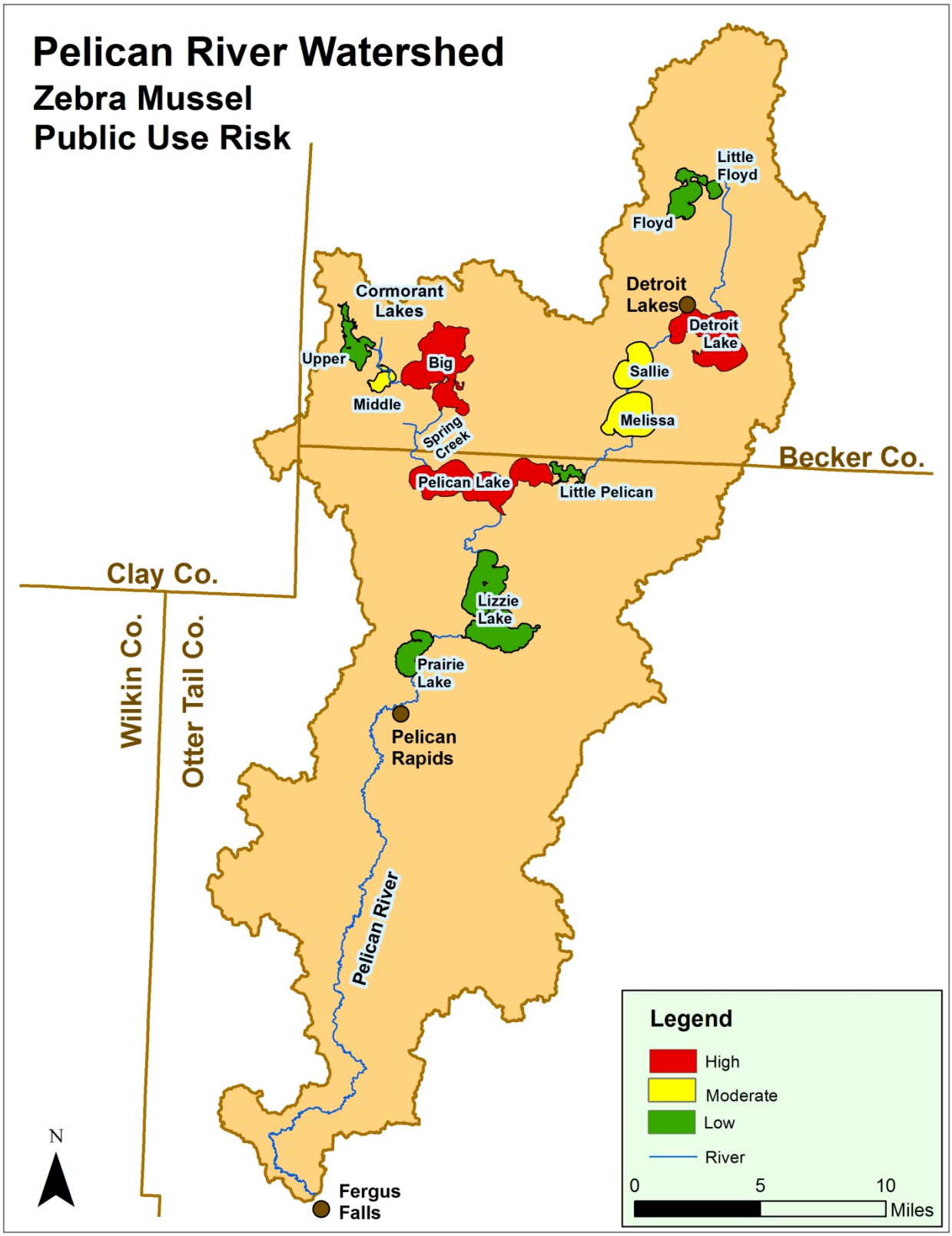


Figure 16. Public use risk rating for lakes in the Pelican River Watershed District.

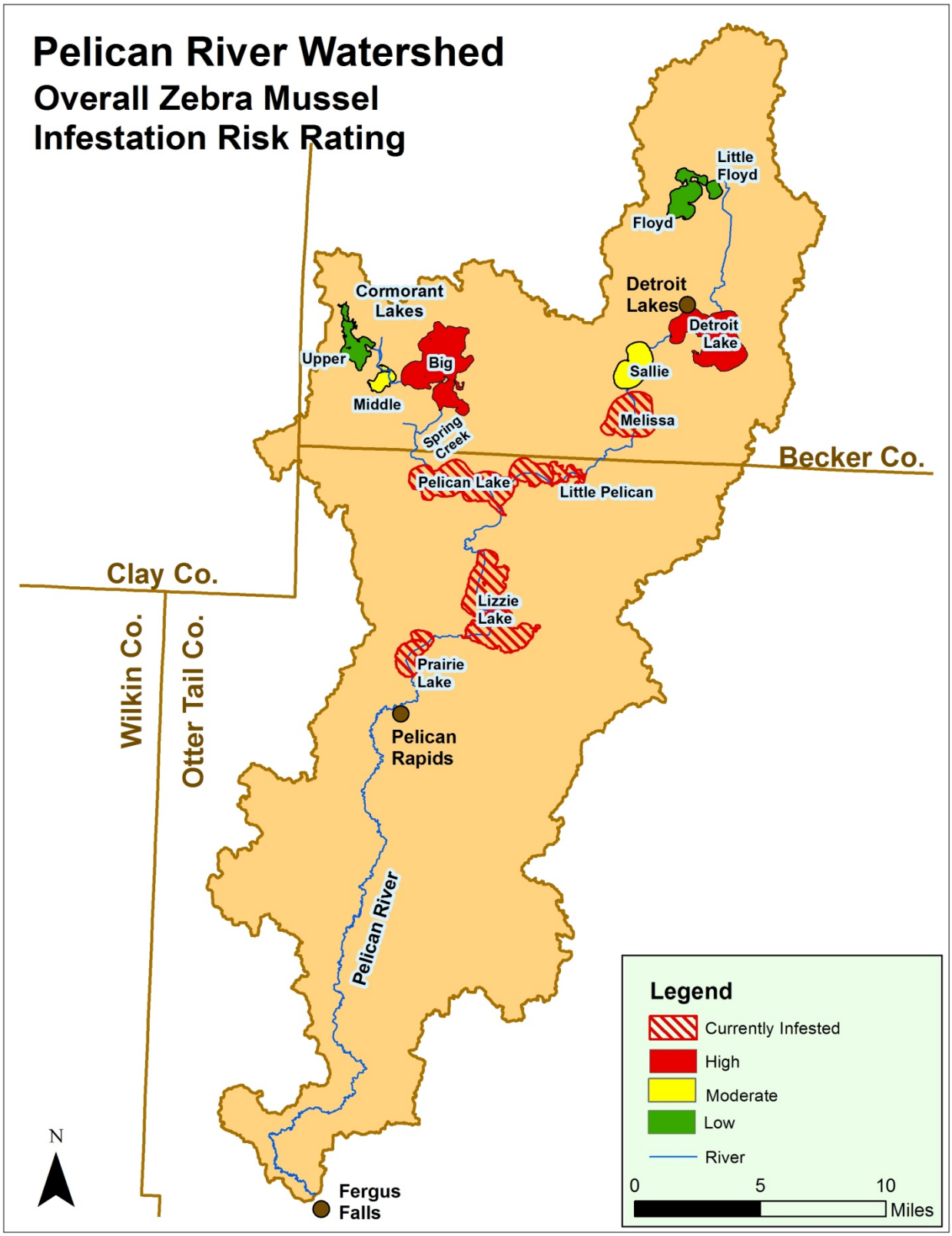


Figure 17. Overall Zebra mussel infestation risk rating in the Pelican River Watershed.

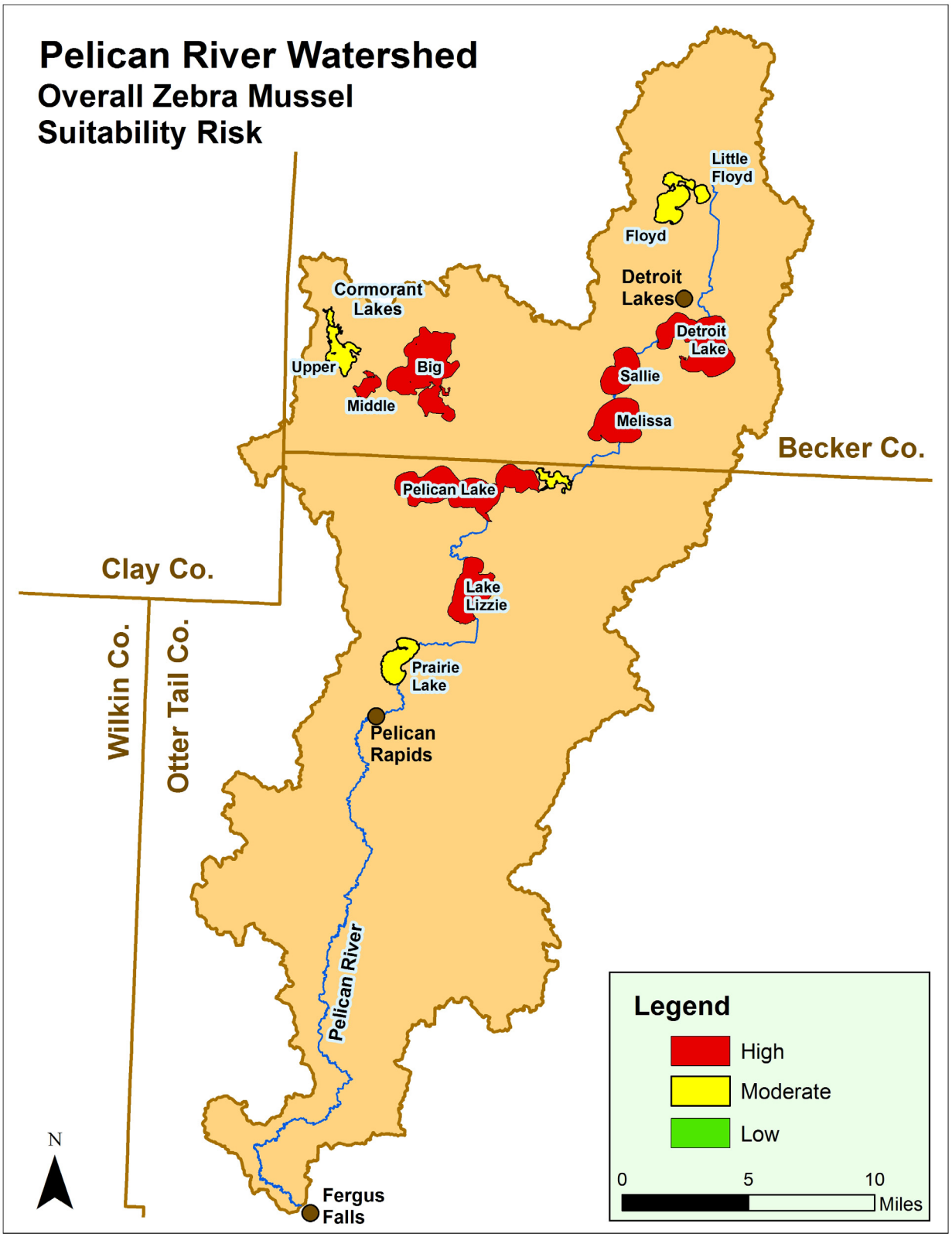


Figure 18. Overall Zebra mussel suitability risk rating in the Pelican River Watershed.

Data Gaps

This study identified some data gaps in the Pelican 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. It is recommended that this data be collected to assist with overall verification of water chemistry. Lakes and streams with populations of freshwater mussels offer an additional level of habitat suitability to also support non-native mussel species. The data gaps are indicated on the lake report cards. See the table below for a summary of parameters needed for each lake (Table 14).

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

Lake Name	Lake ID	Parameters Needed
Upper Cormorant	03-0588-00	Calcium, pH, Alkalinity, Specific Conductance
Middle Cormorant	03-0602-00	Calcium
Big Cormorant	03-0576-00	Calcium
Big Floyd	03-0387-02	Calcium
Little Floyd	03-0386-00	Calcium, Alkalinity
Detroit	03-0381-00	Calcium
Sallie	03-0359-00	Calcium
Melissa	03-0475-00	Calcium
Pelican	56-0786-00	None
Little Pelican	56-0761-00	pH
Lizzie	56-0760-00	Calcium, Specific Conductance
Prairie	56-0915-00	Calcium
Pelican River, Becker County		Calcium, Hardness, Specific Conductance, Turbidity
Pelican River, Otter Tail County		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 are shown in Table 15.

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 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).

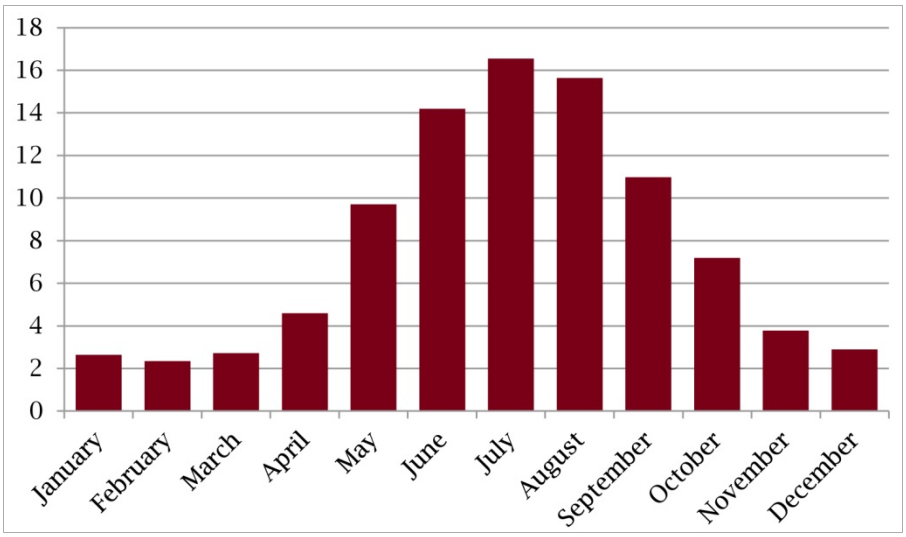


Figure 19. Average number of days occupied per month (n=552) from Pesch & Bussiere 2014.

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

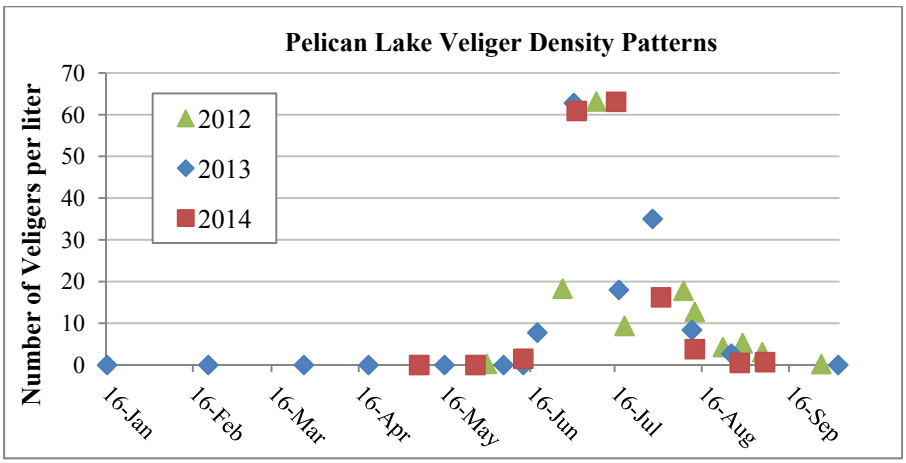


Figure 20. Veliger densities in Pelican Lake, 2012-2014 from Rufer 2015.

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

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.

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: • Detroit • Big Cormorant Priority 2: • Floyd • Upper Cormorant Priority 3: All	Priority 1: July Priority 2: August	County	TBD	This activity depends on available funding. If limited funding is available, focus inspections on Detroit and Big Cormorant in July as the best use of funds.
Early Detection Monitoring: *Adult Zebra mussels*	Priority 1: • Detroit • Big Cormorant Priority 2: All	Priority 1: September Priority 2: Every other week from late June to mid-September	Volunteers	$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.
Early Detection Monitoring: *Zebra mussel veligers*	Detroit Big Cormorant	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
Water Quality Monitoring	See Table 14 for data gaps.	May – September	Lake Associations, COLA	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.
Monitoring: Invasive Plants	Priority 1: • Detroit • Big Cormorant Priority 2: • Floyd • Upper Cormorant Priority 3: 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. Floyd and Upper Cormorant are listed as second priority because they are at the top of the watershed.
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 Detroit Lakes, focus *additional* education around 4th of July since that is the highest risk time of the year for spread.
Decontamination	Melissa Pelican Lizzie Prairie	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 is the priority time of year and what are the priority lakes for each activity. For example, if funding is limited for watercraft inspections at public accesses, the funding should first be used to cover Detroit and Big Cormorant lakes in July. After that, if more funding is available, Detroit and Big Cormorant lakes should have inspectors available in August. After that, if more funding is available, provide inspectors at Floyd and Upper Cormorant Lakes in July, and so forth.

For monitoring, ideally all lakes would be monitored for adults 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.

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