Stressor Identification – Lakes

April 2021

Cottonwood River and Redwood River Watersheds Stressor Identification Report—Lakes

A study of local stressors limiting the biotic communities in lakes within the Cottonwood River and Redwood River Watersheds.

Report prepared for the Minnesota Pollution Control Agency

DEPARTMENT OF NATURAL RESOURCES

WILDLIFE & SPORT FISH RESTORATION

CLEAN WATER LAND & LEGACY AMENDMENT

Author

Derek Bahr (MNDNR)

Contributors/acknowledgements

Lucas Borgstrom (MNDNR)

Jacquelyn Bacigalupi (MNDNR)

Aaron Sundmark (MNDNR)

Taralee Latozke (MNDNR)

Nate Hodgins (MNDNR)

Ryan Doorenbos (MNDNR)

Jonah Dagel (MNDNR)

Jon Lore (MNDNR)

Michael Weckwerth (MPCA)

Matthew Moon (MPCA)

Jeff Strom (Wenck)

Cover photo-Cattails along the shoreline of Island Lake.

Minnesota Department of Natural Resources

500 Lafayette Road | Saint Paul, MN 55155-4194 |

651-296-6157 | 888-646-6367 | Or use your preferred relay service. | Info.dnr@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: wq-ws5-07020006c

Contents

Contents i
List of tables ii
List of figures iii
Key terms and abbreviations iv
Executive summary vi
1. Introduction 1
1.1. Monitoring and assessment of lakes 1
1.2. Stressor identification process 2
1.3. Summary of lake stressors 2
2. Overview of Cottonwood River Watershed and Redwood River Watershed lakes 4
2.1. Background 4
2.2. Monitoring and summary of biological impairments 4
3. Possible stressors to lake fish communities in the CRW and RRW 9
3.1. Candidate causes 9
3.2. Inconclusive causes 9
3.3. Eliminated causes 13
4. Evaluation of candidate causes in impaired lakes in the Cottonwood River Watershed 15
4.1. Double (North Portion; 17-0056-01) 15
4.2. Rock Lake (DOW 42-0052-00) 21
5. Evaluation of candidate causes in impaired and vulnerable lakes in the Redwood River Watershed 27
5.1. Dead Coon Lake (DOW 41-0021-01) 27
5.2. Lake Benton (DOW 41-0043-00) 33
5.3. East Twin Lake (DOW 42-0070-00) 39
5.4. Wood Lake (DOW 42-0078-00) 45
5.5. Island Lake (DOW 42-0096-00) 50
6. Conclusions and recommendations 55
Conclusions 55
Recommendations 56
References 60

List of tables

Table 1. Summary of lake characteristics and metrics for FIBI tools. 1

Table 2. Summary of potential stressors of biological communities in Minnesota lakes. 2

Table 3. Summary of lakes in the Cottonwood River Watershed assessed with FIBI tools. 6

Table 4. Summary of lakes in the Redwood River Watershed assessed with FIBI tools. 6

Table 5. Comparison of common fish species captured in Minnesota River Basin lakes assessed as fully supporting aquatic life use relative to species captured in respective impaired and vulnerable lakes in the Cottonwood River and Redwood River watersheds. 7

Table 6. Interpretation of Score the Shore survey data (From Perleberg et al. 2019). 10

Table 7. Summary of watershed and shoreline stressor information for the two Cottonwood River Watershed lakes that were assessed using FIBI tools. 14

Table 8. Summary of watershed and shoreline stressor information for the five Redwood River Watershed lakes that were assessed using FIBI tools. 14

Table 9. Summary of the stressors associated with the biologically impaired lakes in the Cottonwood River Watershed. 56

Table 10. Summary of the stressors associated with the biologically impaired or vulnerable lakes in the Redwood River Watershed. 56

List of figures

Figure 1. Location of the Cottonwood River and Redwood River watersheds in Minnesota. 4

Figure 2. Cottonwood River Watershed and Redwood River Watershed land cover classes, derived from NLCD 2016 data, with lakes sampled and assessed with FIBI protocols. Lakes that are labeled on the map correspond to lakes assessed as not supporting aquatic life use or inconclusive and vulnerable to future impairment. 5

Figure 3. Examples of bank erosion present around Double Lake. 17

Figure 4. Double Lake (North Portion; 17-0056-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 20

Figure 5. Rock Lake (42-0052-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 26

Figure 6. Dead Coon Lake (41-0021-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 32

Figure 7. Lake Benton (41-0043-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 38

Figure 8. Examples of bank erosion present around East Twin Lake 41

Figure 9. East Twin Lake (42-0070-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 44

Figure 10. Wood Lake (42-0078-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 49

Figure 11. Island Lake (42-0096-00) fish community and stressors; based on fish index of biological integrity (FIBI) results. 54

Key terms and abbreviations

APM ..... Aquatic Plant Management

AMA ..... Aquatic Management Area

BMP ..... Best Management Practice

BWSR..... Minnesota Board of Water and Soil Resources

DOW ..... Division of Waters number; in this report, a unique identification number for water basins in Minnesota. Numbering follows the format of XX-YYYY-ZZ where XX is a county code, YYYY is the basin number in that county, and ZZ is the sub-basin identifier

Contributing watershed .... All upstream areas bounded peripherally by a divide that ultimately drain into a particular watercourse or water body

CRW..... Cottonwood River Watershed

FIBI ..... Fish-based lake index of biological integrity; an index developed by the DNR that compares the types and numbers of fish observed in a lake to what is expected for a healthy lake (range from 0–100). More information can be found at the MNDNR Lake Index of Biological Integrity website

FQI..... Floristic quality index; an index developed by the DNR that assesses anthropogenic effects on plant communities based on plant species tolerance to disturbance (range from 0–46.4, where a lower FQI indicates a less diverse community with fewer intolerant species)

HUC ..... Hydrologic Unit Code

Insectivorous species ..... A species that predominantly eats insects

Intolerant species ..... A species whose presence or abundance decreases as human disturbance increases

Littoral acres ..... In this report, the acres of a lake that are 15 feet deep or less

MDA ..... Minnesota Department of Agriculture

MNDNR ..... Minnesota Department of Natural Resources

MPARS..... Minnesota Department of Natural Resources Permitting and Reporting System

MPCA ..... Minnesota Pollution Control Agency

Nearshore survey ..... In this report, a fisheries survey conducted at evenly spaced, but random sites along the shoreline utilizing 1/8 inch mesh seines and backpack electrofishing to characterize primarily the nongame fish community of a lake

RRW ..... Redwood River Watershed

RIM Reserve Program ……. Reinvest in Minnesota Reserve program; the primary land acquisition program for state held conservation easements and restoration of wetlands and native grasslands on privately owned land in Minnesota

Small benthic-dwelling species …….. A species that is small and predominantly lives in close proximity to the bottom

StS …….. Score the Shore survey; a survey designed by the MNDNR to be able to rapidly assess the quantity and integrity of lakeshore habitat so as to assess differences between lakes and detect changes over time

TMDL …… Total Maximum Daily Load

Tolerant species …… A species whose presence or absence does not decrease, or may even increase, as human disturbance increases

TP …… Total phosphorus; measurement of all forms of phosphorus combined

USEPA …….. United States Environmental Protection Agency

Vegetation-dwelling species …… A species that has a life cycle dependent upon vegetated habitats

Weight of evidence approach …….. A method of using multiple sources or pieces of information to classify a waterbody as impaired

WMA …… Wildlife Management Area

WPA …….. Waterfowl Production Area

WRAPS …… Watershed Restoration and Protection Strategies

Executive summary

Over the past few years, the Minnesota Pollution Control Agency (MPCA) in coordination with the Minnesota Department of Natural Resources (MNDNR) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of the state's lakes. This basic approach is to examine fish communities and related habitat conditions at multiple sites throughout major watersheds. Fish communities in lakes are sampled using a combination of trap nets, gill nets, beach seines, and backpack electrofishing. From these data, a fish-based index of biological integrity (FIBI) score can be developed, which provides a measure of overall fish community health. More information about the sampling and assessment process can be found at the MNDNR lake index of biological integrity website. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification (SID) is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions (Cormier et al. 2000). In simpler terms, it is the process of identifying the major factors causing harm to aquatic life. SID is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes SID work related to lakes in the Cottonwood River Watershed (CRW) and Redwood River Watershed (RRW). Similar SID work has also occurred for biologically impaired streams in the CRW (MPCA 2021a) and RRW (MPCA 2021b). The CRW encompasses over 840,000 acres and the RRW encompasses over 440,000 acres. Both watersheds are characterized predominantly as cultivated agricultural land and contain several lakes, rivers, and streams. Cities within the CRW and RRW include Marshall, Redwood Falls, and New Ulm.

Of the lakes within the CRW and RRW, seven were sampled and assessed using the FIBI to evaluate biological health. Of the lakes that were sampled, six were assessed as not supporting aquatic life use based on FIBI scores that were below the impairment threshold established for similar lakes. One additional lake was considered to have insufficient information to make an assessment decision based on a limited sampling history; however, it was considered vulnerable to future impairment.

After examining many candidate causes for the biological impairments, the following was identified as a probable cause of stress to aquatic life within the CRW and RRW:

- Eutrophication

This SID report follows a format to first summarize candidate causes of stress to the biological communities at the 8-digit hydrologic unit code (HUC) scale. Within the summary (Section 3), there is information about how each stressor relates broadly to the CRW and RRW, water quality standards, and general effects on biology. Sections 4 and 5 are organized by major watershed and Division of Waters (DOW) number. Each section discusses the available data and relationships to the fish communities in more detail.

1. Introduction

1.1. Monitoring and assessment of lakes

The approach used to identify biological impairments in lakes includes the assessment of fish communities present in lakes throughout a major watershed. The fish-based lake index of biological integrity (FIBI) utilizes fish community data collected from a combination of trap nets, gill nets, beach seines, and backpack electrofishing. From this data, an FIBI score can be calculated for each lake that provides a measure of overall fish community health based on species diversity and composition. The MNDNR has developed four FIBI tools to assess different types of lakes throughout the state (Bacigalupi et al. 2021; Table 1). More information on FIBI tools and assessments based on the FIBI can be found at the MNDNR lake index of biological integrity website. Although an FIBI score may indicate that a lake's fish community is impaired, a weight of evidence approach is still used during the assessment process that factors in considerations such as sampling effort, sampling efficiency, tool applicability, location in the watershed, and any other unique circumstances to validate the FIBI score.

A common misconception regarding assessment decisions based on the FIBI is that if a lake supports a quality gamefish population (e.g., high abundance or desirable size structure of a popular gamefish species), that lake should be considered healthy. This is not necessarily true because both game-and nongame fish species must be considered when holistically evaluating fish community health. Oftentimes, the smaller nongame fishes serve ecologically important roles in aquatic ecosystems and are generally the most sensitive to human-induced stress. Likewise, high abundance or quality size structure of gamefish populations will not disproportionately affect the FIBI score because multiple metrics are used to evaluate different components of the fish community and each contributes equal weight to the total FIBI score.

Table 1. Summary of lake characteristics and metrics for FIBI tools.

	FIBI tool			
Lake characteristics	**2**	**4**	**5**	**7**
Generally deep (many areas greater than 15' deep)	X	X		
Generally shallow (most areas less than 15' deep)			X	X
Generally with complex shape (presence of bays, points, islands)	X		X	
Generally with simpler shape (lack of bays, points, and islands)		X		
Species richness metrics				
Number of native species captured in all gear	X			
Number of intolerant species captured in all gear	X	X	X	
Number of tolerant species captured in all gear	X	X	X	X
Number of insectivorous species captured in all gear	X			X
Number of omnivorous species captured in all gear	X	X	X	
Number of cyprinid species captured in all gear	X			
Number of small benthic-dwelling species captured in all gear	X	X		X
Number of vegetation-dwelling species captured in all gear	X	X		X
Community composition metrics				

	FIBI tool			
Lake characteristics	**2**	**4**	**5**	**7**
Relative abundance of intolerant species in nearshore sampling	X		X	
Relative abundance of small benthic-dwelling species in nearshore sampling	X	X		
Relative abundance of vegetation-dwelling species in nearshore sampling				X
Proportion of biomass in trap nets from insectivorous species	X	X	X	X
Proportion of biomass in trap nets from omnivorous species	X	X	X	
Proportion of biomass in trap nets from tolerant species	X	X	X	X
Proportion of biomass in gill nets from top carnivore species	X	X	X	X
Presence/absence of Intolerant species captured in gill nets	X	X		
Total number of metrics used to calculate FIBI	**15**	**11**	**8**	**8**

1.2. Stressor identification process

Stressor identification (SID) is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems. The process provides a structure for organizing scientific evidence to support conclusions (Cormier et al. 2000). In simpler terms, it is the process of identifying the major factors causing harm to aquatic life. Stressor identification is a key component of the major watershed restoration and protection strategy (WRAPS) projects being carried out under Minnesota's Clean Water Legacy Act. Similar to this stressor identification report for lakes, the MPCA has also completed a stressor identification report for impaired streams in the CRW (MPCA 2021a) and RRW (MPCA 2021b) watersheds.

1.3. Summary of lake stressors

The MNDNR has developed a separate document that describes the various stressors of biological communities in lakes, including where they are likely to occur, their mechanism of harmful effect, Minnesota's standards for those stressors where applicable, and the types of data available that can be used to evaluate each stressor (MNDNR 2018a; Table 2). Many literature references are cited, providing additional sources of information. The document is entitled "Stressors to Biological Communities in Minnesota's Lakes" and can be found on the MNDNR lake index of biological integrity website. Additionally, the United States Environmental Protection Agency (USEPA) has information, conceptual diagrams of sources and causal pathways, and publication references for numerous stressors to aquatic ecosystems on their CADDIS website.

Table 2. Summary of potential stressors of biological communities in Minnesota lakes.

Stressor	Examples of anthropogenic sources	Examples of links to aquatic biology
Eutrophication	Inputs of excessive nutrients from agricultural runoff, animal waste, fertilizer, industrial and municipal wastewater facility discharges, non-compliant septic system effluents, and urban stormwater runoff	Detrimental changes to aquatic plant diversity and abundance, restructuring of plankton communities, detrimental effects to vegetation-dwelling and sight-feeding predatory fishes

Stressor	Examples of anthropogenic sources	Examples of links to aquatic biology
Physical habitat alteration	Riparian lakeshore development, aquatic plant removal, non-native species introductions, water level management, impediments to connectivity, sedimentation	Detrimental changes to aquatic plant diversity and abundance, reduced diversity and abundance of habitat specialists, reductions in spawning success
Altered interspecific competition	Unauthorized bait bucket introductions or unintentional transport, introductory and supplemental stocking activities by management agencies or private parties, angler harvest	Detrimental changes to energy flow, reductions in native species diversity and abundance through predation or competition for resources
Temperature regime changes	Climate change resulting from emission of greenhouse gases	Physiological stress and reduced survival, particularly for intolerant coldwater fishes, increases in aquatic plant biomass and distribution
Decreased dissolved oxygen	Inputs of excessive nutrients, climate change resulting from emission of greenhouse gases	Suffocation, detrimental effects to locomotion, growth, and reproduction of intolerant fishes
Increased ionic strength	Road salt and de-icing product applications, industrial runoff and discharges, urban stormwater and agricultural drainage, wastewater treatment plant effluent	Detrimental effects to intolerant fishes and other aquatic organisms
Pesticide application	Herbicide applications to aquatic plant communities, runoff and drift from herbicide and insecticide applications to agricultural, suburban, and urban areas	Reduced aquatic plant biomass, reduced abundance and diversity of vegetation-dwelling fishes
Metal contamination	Runoff and leaching from mining operations, industrial sites, firing ranges, urban areas, landfills, and junkyards	Reduced survival, growth, and reproduction of fishes
Unspecified toxic chemical contamination	Runoff and leaching from industrial sites, agricultural areas, mining, logging, urban and residential activities, and landfills, spills, illegal dumping, and discharges from industries, municipal treatment facilities, and animal husbandry operations	Altered food web dynamics, reduced fitness of fishes from chronic exposure

2. Overview of Cottonwood River Watershed and Redwood River Watershed lakes

2.1. Background

The Cottonwood River Watershed (CRW) encompasses over 840,000 acres and the Redwood River Watershed (RRW) encompasses over 440,000 acres. Both watersheds are characterized predominantly as cultivated agricultural land and both contain several lakes, rivers, and streams. Cities within the CRW and RRW include Marshall, Redwood Falls, and New Ulm. From east to west, the CRW and RRW are contained within two ecoregions: Western Corn Belt Plains and Northern Glaciated Plains (Figure 1).

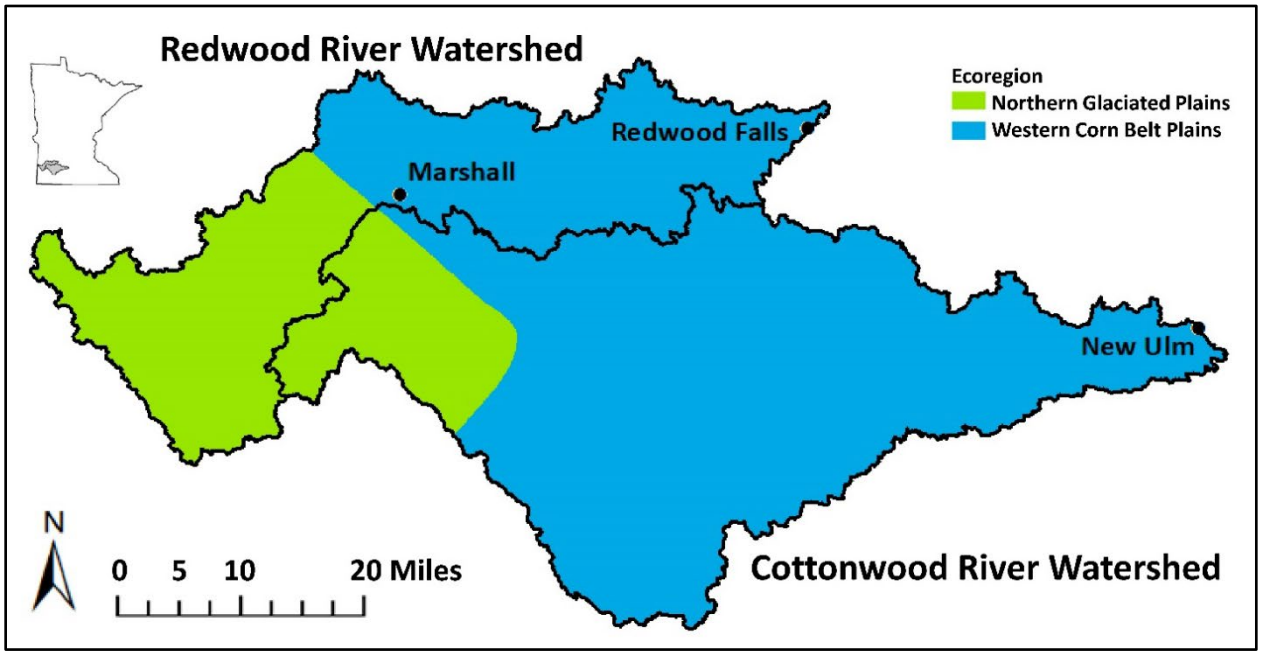


Figure 1. Location of the Cottonwood River and Redwood River watersheds in Minnesota.

2.2. Monitoring and summary of biological impairments

FIBI tool 7 was used to assess two lakes in the CRW and five lakes in the RRW (Figure 2; Table 3; Table 4). A total of two lakes in the CRW and four lakes in the RRW had FIBI scores below the impairment threshold (i.e., 36; 90% confidence interval: 27–45) and were assessed as not supporting aquatic life use (Figure 2; Table 3; Table 4). These lakes include Double (North Portion; 17-0056-01), Dead Coon (41-0021-01), Benton (41-0043-00), Rock (42-0052-00), East Twin (42-0070-00), and Wood (42-0078-00). One additional lake, Island Lake (42-0096-00), in the RRW was considered to have insufficient information to make an assessment decision based on a limited sampling history; however, it was considered vulnerable to future impairment (Table 4). The remainder of this document will review stressor information for the CRW and RRW lakes that were either assessed as not supporting aquatic life use or considered vulnerable to future impairment.

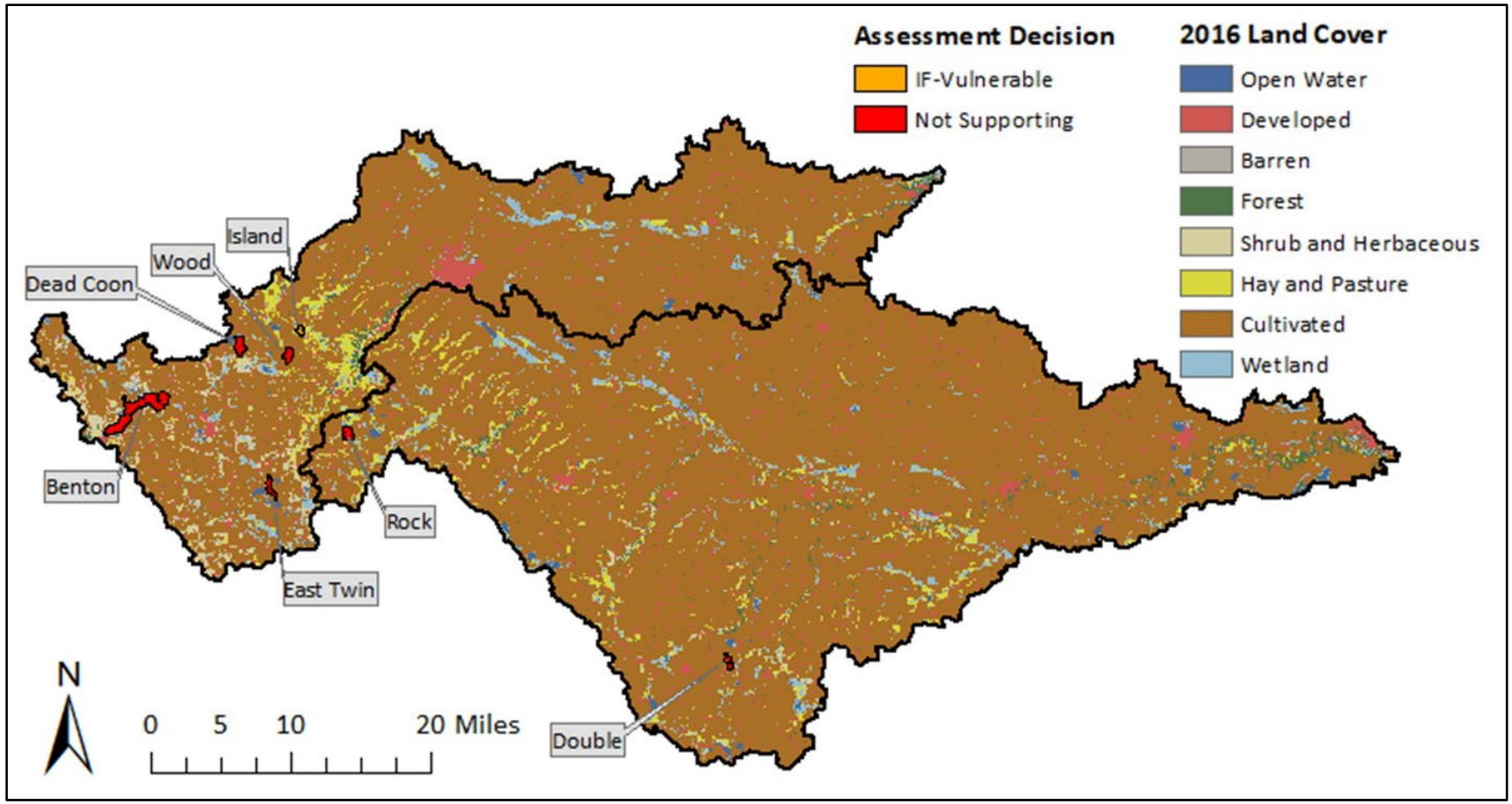


Figure 2. Cottonwood River Watershed and Redwood River Watershed land cover classes, derived from NLCD 2016 data, with lakes sampled and assessed with FIBI protocols. Lakes that are labeled on the map correspond to lakes assessed as not supporting aquatic life use or inconclusive and vulnerable to future impairment.

Table 3. Summary of lakes in the Cottonwood River Watershed assessed with FIBI tools.

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% Littoral[1]	FIBI score(s)	Below impairment threshold	Assessment status[2]
17-0056-01	Double (North Portion)	Cottonwood	2015	South portion inaccessible for sampling	136	7	100	17	Yes	NS
42-0052-00	Rock	Lyon	2014	N/A	379	7	100	3	Yes	NS
≤ lower CL		> lower CL & ≤ threshold		> threshold & ≤ upper CL		> upper CL			Insufficient Information	

[1] % littoral is the percentage of the lake that is less than 15 feet deep calculated using MNDNR GIS data.
[2] "NS" indicates not supporting aquatic life use, "IF" indicates insufficient information, and "Vuln" indicates vulnerable to future impairment.

Table 4. Summary of lakes in the Redwood River Watershed assessed with FIBI tools.

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% Littoral[1]	FIBI score(s)	Below impairment threshold	Assessment status[2]
41-0021-01	Dead Coon	Lincoln	2014, 2017	Low sampling effort (2014)	547	7	100	5, 5	Yes, Yes	NS
41-0043-00	Benton	Lincoln	2011, 2017	Sampling completed outside of assessment window (2011)	2,699	7	100	15, 12	Yes, Yes	NS
42-0070-00	East Twin	Lyon	2016, 2016	N/A	356	7	63	13, 14	Yes, Yes	NS
42-0078-00	Wood	Lyon	2012, 2016	Sampling completed outside of assessment window (2011)	373	7	100	16, 4	Yes, Yes	NS
42-0096-00	Island	Lyon	2018	Limited sampling history to determine likelihood of winterkill events	170	7	100	13	Yes	IF-Vuln
≤ lower CL		> lower CL & ≤ threshold		> threshold & ≤ upper CL		> upper CL			Insufficient Information	

[1] % littoral is the percentage of the lake that is less than 15 feet deep calculated using MNDNR GIS data.
[2] "NS" indicates not supporting aquatic life use, "IF" indicates insufficient information, and "Vuln" indicates vulnerable to future impairment.

Table 5. Comparison of common fish species (occurring in 50% or more of lakes) captured[1] in Minnesota River Basin lakes assessed as fully supporting aquatic life use (marked with an "X" in the Minn R. Basin lakes column) relative to species captured in respective impaired and vulnerable lakes in the Cottonwood River and Redwood River watersheds.

Species	Tolerance, feeding, and/or habitat guild[2]	Minn R. Basin lakes	Double (North Portion) 17-0056-01	Rock 42-0052-00	Dead Coon 41-0021-01	Benton 41-0043-00	East Twin 42-0070-00	Wood 42-0078-00	Island 42-0096-00
Bigmouth Buffalo	Tol, Ins	X	GN, TN	NS					
Black Bullhead	Tol	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	GN, TN	NS, GN, TN
Black Crappie	TC	X	NS, GN, TN	NS	NS, TN	NS, GN, TN	GN, TN		
Bluegill	Ins	X	TN			NS, GN, TN	NS, TN	NS, TN	
Brook Stickleback	Ins					NS			
Bluntnose Minnow		X							
Brown Bullhead		X							NS, GN, TN
Channel Catfish	TC		NS, GN	NS, GN, TN					
Common Carp	Tol	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, TN	NS, GN, TN	
Fathead Minnow	Tol	X	NS	NS	NS	NS		NS	NS
Freshwater Drum	Ins	X	GN						
Golden Shiner		X							
Green Sunfish	Tol, Ins	X	NS, TN	NS		NS, TN		NS	NS, TN
Iowa Darter	Ins, Smb, Veg	X	NS			NS	NS	NS	
Johnny Darter	Ins, Smb	X		NS	NS	NS		NS	
Largemouth Bass	TC	X	NS			TN		NS, GN, TN	
Northern Pike	Veg, TC	X	GN	GN, TN	NS, GN, TN	GN, TN			NS, GN, TN
Orangespotted Sunfish	Tol, Ins		NS	NS, TN	NS	NS			
Pumpkinseed	Ins	X							
Shorthead Redhorse	Ins		GN						
Smallmouth Bass	TC						NS		
Spottail Shiner	Ins	X							
Walleye		X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	

Species	Tolerance, feeding, and/or habitat guild[2]	Minn R. Basin lakes	Double (North Portion) 17-0056-01	Rock 42-0052-00	Dead Coon 41-0021-01	Benton 41-0043-00	East Twin 42-0070-00	Wood 42-0078-00	Island 42-0096-00
White Crappie	TC	X	TN						
White Sucker		X	GN	GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	
Yellow Bullhead		X	NS, GN, TN						
Yellow Perch	Ins	X	NS, GN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	GN, TN	NS, GN, TN

[1]Sampling methods that the species were captured with are abbreviated as follows: NS=Backpack Electrofishing and Seining, GN=Gill Netting, and TN=Trap Netting.
[2]Tolerance, feeding, and habitat guilds are abbreviated as follows: Tol=tolerant, Ins=insectivore, TC=top carnivore, Smb=small benthic-dweller, and Veg=vegetation-dweller. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

3. Possible stressors to lake fish communities in the CRW and RRW

3.1. Candidate causes

Eutrophication

Land use disturbance and excess nutrients such as TP have been identified as causes of eutrophication in lakes. Water quality measurements taken in the 7 CRW and RRW lakes assessed for aquatic life use indicate that mean summer TP averages 142.8 ppb and varies from 37.4 ppb to 238.8 ppb (Table 7; Table 8). Similarly, land use disturbance in the contributing watershed for each lake averages 68.6% and varies from 49.8% to 81.7% (Table 7; Table 8; MNDNR 2018b). All of the lakes are located in watersheds that exceed 40% land use disturbance (i.e., agricultural, developed, and/or mining), a level at which TP levels can be significantly elevated (Cross and Jacobson 2013). Further, cultivated agricultural land comprises 68.6% to 97.8% of all disturbed land within each contributing watershed. Concurrent with high agricultural land use, extensive drain tiling and substantial loss of wetlands have also occurred throughout the CRW and RRW. Drain tiling in particular has altered hydrography and has resulted in increased nutrient influxes into lakes. Approximately 77% of the lakes assessed by MPCA for aquatic recreation within the CRW and RRW (excluding insufficient or inconclusive information determinations) are impaired based on MPCA's nutrient water quality standards (Minnesota Rules Chapter 7050). The standards require that TP and either chlorophyll-a or transparency need to exceed an established threshold to be listed as impaired. MPCA's nutrient water quality standards have been established for aquatic recreation use; however, fish communities may exhibit responses at lower threshold levels. Given the above information, eutrophication will be evaluated further as a potential stressor within the CRW and RRW.

3.2. Inconclusive causes

Physical habitat alteration

MNDNR Score the Shore (StS) data (Perleberg et al. 2019) indicates that lakes within the CRW and RRW have more riparian shoreline disturbance on average than lakes statewide, although lakes were not selected at random and protocols have changed slightly to better characterize the shoreland and shoreline of lakes located in prairie regions of the state. Nonetheless, the average StS score for lakes within the CRW and RRW was 66, which is lower than the statewide average of 73 (Table 7; Table 8). Aside from Lake Benton, a majority of the developed sites on each lake were classified as agricultural land use, which is in sharp contrast to many lakes in central and northern Minnesota. The average scores for shoreland, shoreline, and aquatic areas associated with each of the lakes were 13.5, 24.2, and 28.6, respectively. "Low" StS scores, as defined in Table 6, are indicative of disturbed riparian lakeshore habitat whereas "high" StS scores are indicative of relatively undisturbed riparian lakeshore habitat (Perleberg et al. 2019). These results indicate that shoreland habitat loss (i.e., the lack of a riparian buffer beyond a lake's immediate shoreline) in particular may be higher around lakes within the RRW

and CRW than lakes statewide, but that shoreline and aquatic habitat has been altered to a lesser extent.

Table 6. Interpretation of Score the Shore survey data (From Perleberg et al. 2019).

Mean lakewide score	Mean shoreland score	Mean shoreline score	Mean aquatic score	Rating
85-100	28-33.3	28-33.3	28-33.3	High
66-84	22-27	22-27	22-27	Moderate
50-65	17-21.5	17-21.5	17-21.5	Low
<50	<17	<17	<17	Very Low

An alternative measure, dock density, can also be used to evaluate the level of disturbance from residential development occurring along the shoreline of a lake. Dock densities exceeding 16 docks per mile can significantly affect fish communities and habitat (Jacobson et al. 2016; Dustin and Vondracek 2017). However, of the seven lakes in the CRW and RRW that were assessed for aquatic life use, none had dock densities exceeding 16 docks per mile. Dock density averaged only 2.4 docks per mile and varied from 0.4 to 9.6 docks per mile (Table 7; Table 8). As such, residential shoreline development is not a likely stressor; however, cultivation of land for row crops in the immediate shoreland area of many of these lakes may be negatively affecting physical habitat in addition to contributing excess nutrients.

Aside from permits issued to chemically treat Curly-leaf Pondweed in Lake Benton, a review of MNDNR Permitting and Reporting System (MPARS) information indicates that no other permits have been issued to mechanically or chemically remove emergent, floating-leaf, or submersed plants on the assessed lakes within the CRW and RRW. However, removal of submersed plants outside of the date range of available permit data, removal that does not require a permit, or illegal removal may occur within the CRW and RRW.

A review of non-native species that would have the potential to alter physical habitat, including aquatic plant community structure, indicates that several species—Common Carp and Curly-leaf Pondweed—are present in a subset of lakes within the CRW and RRW.

A review of the Minnesota inventory of dams indicates that there are 78 dams located within the CRW and 28 within the RRW; however, not all water control structures may be identified or included in this inventory. Minimal quantitative data is available describing fish habitat conditions prior to engaging in long-term water level management on lakes within the watershed and the effects of water level management on the FIBI score are unknown. Therefore, water level management is an inconclusive stressor due to a lack of data from which to draw conclusions.

A review of the MNDNR Watershed Health Assessment Framework (WHAF) tool indicates that the potential for aquatic disruption from culverts, bridges, and dams is higher than the statewide average (MNDNR 2018b). A lower score indicates higher potential for aquatic disruption, and the CRW and RRW score 36 and 22, respectively, out of a possible 100, whereas the statewide average is 53. Preliminary data from the MNDNR Culvert Inventory is also available for culverts in the CRW that have been assessed to date. Of the 229 culverts that have been evaluated in the CRW, 28% create a possible barrier to fish passage at some flows due to their size, function, or design (A. Hillman, MNDNR, unpublished data). Additional information related to connectivity within the CRW is included in the Cottonwood River Watershed Characterization Report (MNDNR 2020a). Similar data regarding fish passability for the 131

culverts in the RRW are unavailable; however, connectivity in the RRW is described in greater detail in the Redwood River Watershed Characterization Report (MNDNR 2020b).

A review of sedimentation data indicates that measures such as total suspended solids or substrate embeddedness are lacking for most lakes within the CRW and RRW. Although sedimentation may contribute to lower than expected FIBI scores for certain lakes, the lack of high quality quantitative data and scientific research on the topic makes it challenging to draw conclusions for lakes within the CRW and RRW.

Altered interspecific competition

A review of MNDNR survey data indicates that the CRW and RRW are affected by non-native species that can directly compete with native fish species for resources. At least six of the seven assessed lakes within the watersheds contain Common Carp, which have the potential to directly compete with native fishes.

A review of gamefish management activities indicates that stocking and harvest regulations occur in many lakes within the CRW and RRW. While some gamefish management activities can result in significant changes to the fish community of a lake, in general, there is an overall lack of conclusive evidence linking these changes to FIBI scores. Therefore, gamefish management activities are considered inconclusive as potential stressors to the fish community because the effects of gamefish management on the FIBI score are unknown.

Decreased dissolved oxygen

Data regarding dissolved oxygen concentrations in lakes is generally limited to discrete profiles collected during periodic MPCA and MNDNR surveys or is provided as anecdotal information when related to summerkill or winterkill events. As such, limited information exists to indicate whether human-induced changes in dissolved oxygen concentrations are occurring in a manner that might result in changes to fish communities, and specifically coolwater and warmwater species, present in the CRW and RRW.

Further, winterkill events are a natural occurrence in many shallow lakes, although in some instances, the frequency and severity of winterkill events are exacerbated by human-caused stressors such as eutrophication (Greenbank 1945, Mathias and Barica 1980, Meding and Jackson 2003). Due to difficulties in parsing out natural winterkill from eutrophication-exacerbated winterkill, the FIBI is utilized to assess lakes where effects of winterkill are minimal on the current fish community—based on species composition and size- and age-structure data—with the assumption that the fish community in an assessed lake is influenced by human-caused stressors rather than by natural winterkill. As such, surveys on all lakes assessed for aquatic life use in the CRW and RRW indicated sufficient winter dissolved oxygen levels—either naturally or sustained by winter aeration systems—and a variety of species and size- and age-classes of fish observed in recent decades. Lakes that have winter aeration systems include Double, Rock, Dead Coon, Benton, and East Twin. Although winter dissolved oxygen levels were sufficient in lakes that utilized aeration systems, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to the aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, although specific effects have not been thoroughly evaluated. Decreased dissolved oxygen is therefore considered inconclusive as a primary stressor to impaired CRW or RRW fish communities.

Pesticide application

Pesticide application may contribute to the impaired fish communities in the CRW and RRW; however, since the most prominent agricultural pesticide types used in the watershed are often not monitored, conclusive evidence that these toxins are a source of impairment is lacking.

According to a USEPA report by Atwood and Paisley-Jones (2017), farmers in the United States account for 20% of global pesticide use. In 2017, the most commonly sold pesticides to Minnesota agricultural producers, ranked by weight, were glyphosate (herbicide), acetochlor (herbicide), metam sodium (fungicide), metolachlor (herbicide), atrazine (herbicide), and chlorpyrifos (insecticide; MDA 2020); however, these estimates do not include pesticide seed treatments. Seed treatments have recently become widely adopted, with a majority of row crop seeds treated with pesticides such as neonicotinoids prior to planting. Neonicotinoids, broad-spectrum systemic insecticides, are the fastest growing class of insecticides worldwide and are now registered for use on hundreds of field crops in over 120 different countries (Morrissey et al. 2015; Douglas and Tooker 2015). Coating seeds with insecticide as a method of pest management poses a particular risk to aquatic environments as most seed-applied neonicotinoids (80–98%) fail to enter treated plants and instead dissolve into soil water (Goulson 2014).

Pesticides can affect fish communities through several pathways. Direct effects to fish include nervous, metabolic, and endocrine system disruptions, as well as negative effects to ontogenetic development (Köhler and Triebskorn 2013). Chlorpyrifos, a commonly used insecticide, has been found to be highly toxic to fish (e.g., Bluegill Sunfish LC_{50} = 1.8 ppb) and aquatic invertebrates (e.g., Daphnia LC_{50} = 0.1 ppb) on an acute basis (Corbin and Flaherty 2009). Aquatic invertebrates, often more sensitive to agricultural pesticides than their terrestrial relatives (Krupke and Tooker 2020), mediate indirect negative effects on fish abundances and community structure (Yamamuro et al. 2019). For example, Yamamuro et al. (2019) observed a 91% reduction in average annual yields of Rainbow Smelt in a freshwater lake within a primarily agricultural watershed and attributed the reduction to neonicotinoid pesticide contamination resulting in a lack of invertebrate prey. As many waterbodies in Minnesota share similar agricultural watershed characteristics, it is plausible that pesticides are negatively affecting FIBI scores either through direct or indirect means. Indirect impacts are common with pesticide application, and often unrelated to the toxicity on the species ultimately affected. The indirect pathway by which pesticides can reduce the abundance of prey available for insectivorous fishes is a critical consideration for maintaining healthy aquatic ecosystems composed of appropriately balanced native fish communities, and is likely of greater concern than the direct effects to the fishes themselves.

Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019). Approximately 86% of the land use in the CRW and 80% in the RRW is categorized as cultivated agricultural land (MNDNR 2018b). In the broader Upper Mississippi-Minnesota River Basin (HUC4: 0702), corn and soybean production accounted for 53% and 46% of agricultural acres, respectively (USDA 2017). Insecticides were applied to 40% of agricultural acres in 2017, and herbicides applied to 88% (USDA 2017); however, Douglas and Tooker (2015) suggest that 79–100% of corn acres and 34–44% of soybean acres are also planted using neonicotinoid-coated seeds in the United States. Extrapolations suggest that 49–63% percent of all land within the CRW is planted using treated seeds and that other insecticides and herbicides may also be applied to 34% and 76% of all land, respectively. Similarly, 46–56% within the RRW is planted using treated seeds and other insecticides and herbicides may be applied to 32% and 71% of all land, respectively.

Despite relatively limited information, pesticide monitoring has resulted in the designation of one CRW stream, Sleepy Eye Creek, and one RRW stream, Three Mile Creek, as impaired for chlorpyrifos on MPCA's 2020 impaired waters list (MDA 2018; MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Cottonwood River (e.g., clothianidin, imidacloprid, and chlorpyrifos) and Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos). Although most lakes within the CRW and RRW were not sampled for pesticides, a detection of chlorpyrifos above the applicable chronic standard (i.e. >0.041 ppb) occurred in Double Lake, resulting in inclusion of Double Lake on MPCA's 2020 impaired waters list for pesticides (MDA 2018; MPCA 2020a).

3.3. Eliminated causes

Temperature regime changes

A review of Minnesota climate trends (MNDNR 2020c) indicates that mean July air temperatures within the CRW and RRW may have increased by an average of 0.08 °F per decade over the last century as a result of climate change. Increases in air temperature have been shown to be correlated with increases in water temperature (Robertson and Ragotzkie 1990). Although evidence suggests that water temperature has increased in lakes within the CRW and RRW, limited research is available to demonstrate the magnitude of change needed to result in changes to the fish community as indicated by the FIBI.

Increased ionic strength

A review of MPCA's Impaired Waters List indicates that no lakes within the CRW or RRW were assessed as impaired for aquatic life use based on the chronic standard for chloride (MPCA 2020a). Chloride concentrations that are toxic to fish and other aquatic organisms would need to exceed the aquatic life use standards. Therefore standards and actions intended to address chloride impairments should provide adequate protection to eliminate chloride as a likely candidate cause for impaired fish communities in the CRW or RRW.

Metal contamination

A review of MPCA's Impaired Waters List (MPCA 2020a) indicates that the CRW and RRW contain four lakes that have been identified as impaired for aquatic consumption based on mercury levels; however, MPCA and local partners have developed a statewide mercury reduction plan approved by the USEPA to address these impairments (MPCA 2007). Mercury concentrations that are toxic to fish and other aquatic organisms would need to far exceed the aquatic consumption standards. Therefore, standards and actions intended to address aquatic consumption impairment should provide adequate protection to eliminate mercury as a likely candidate cause for impaired fish communities in the CRW and RRW.

Unspecified toxic chemical contamination

A review of publicly accessible MPCA data indicated that most properties that generate hazardous waste were located around the major population centers within the CRW and RRW (e.g., Marshall, Redwood Falls, and New Ulm), and that they were not likely a significant stressor to fish communities (MPCA 2020b).

Table 7. Summary of watershed and shoreline stressor information for the two Cottonwood River Watershed lakes that were assessed using FIBI tools.

DOW	Lake name	FIBI tool	Assessment status[1]	Percent watershed disturbance[2]	Total phosphorus (ppb)[3]	Dock density (#/mi)[4]	Score the Shore score[5]
17-0056-01	Double (North Portion)	7	NS	64.3	93.6	2.7	NA
42-0052-00	Rock	7	NS	81.7	238.8	1.6	72

[1] "NS" indicates not supporting aquatic life use.
[2] Percent watershed disturbance is calculated as the percentage of land in each lake's contributing watershed that was classified as developed, agricultural, or barren based on 2016 National Land Cover Database land use data.
[3] Total phosphorus is calculated as the 10-year average of measurements taken June 1-September 30, 2009-2018.
[4] Dock density is estimated from counts of docks visible on Google Earth in 2015.
[5] Score the sore scores (Perleberg et al. 2019) assess the quantity and integrity of lakeshore habitat.

Table 8. Summary of watershed and shoreline stressor information for the five Redwood River Watershed lakes that were assessed using FIBI tools.

DOW	Lake name	FIBI tool	Assessment status[1]	Percent watershed disturbance[2]	Total phosphorus (ppb)[3]	Dock density (#/mi)[4]	Score the Shore score[5]
41-0021-01	Dead Coon	7	NS	73.4	142.1	0.7	69
41-0043-00	Benton	7	NS	66.9	197.8	9.6	65
42-0070-00	East Twin	7	NS	49.8	37.4	0.4	66
42-0078-00	Wood	7	NS	65.6	167.6	1.2	58
42-0096-00	Island	7	IF-Vuln	78.3	122.5	0.4	67

[1] "NS" indicates not supporting aquatic life use, "IF" indicates insufficient information, and "Vuln" indicates vulnerable to future impairment.
[2] Percent watershed disturbance is calculated as the percentage of land in each lake's contributing watershed that was classified as developed, agricultural, or barren based on 2016 National Land Cover Database land use data.
[3] Total phosphorus is calculated as the 10-year average of measurements taken June 1-September 30, 2009-2018.
[4] Dock density is estimated from counts of docks visible on Google Earth in 2015.
[5] Score the sore scores (Perleberg et al. 2019) assess the quantity and integrity of lakeshore habitat.

4. Evaluation of candidate causes in impaired lakes in the Cottonwood River Watershed

Two lakes in the CRW were assessed as not supporting aquatic life use because they had FIBI scores that were below the impairment threshold (Table 3). These lakes include Double (North Portion; 17-0056-01) and Rock (42-0052-00). Causes of stress to the fish communities in these impaired lakes are evaluated.

4.1. Double (North Portion; 17-0056-01)

The north portion of Double Lake (hereafter referred to as Double Lake) is 136 acres in size and has a maximum depth of 9 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Double Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Double Lake and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, decreased dissolved oxygen, and pesticide application have been identified as inconclusive stressors (Figure 4). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Double Lake was sampled using seining, backpack electrofishing, gill netting, and trap netting during June 2015. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI score, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicates the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI score of 17 was below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Double Lake.

During the 2015 FIBI survey, 19 fish species were captured (Table 5). All six species classified as tolerant in the FIBI (i.e., Bigmouth Buffalo, Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish, and Orangespotted Sunfish) were sampled, and the proportion of biomass from tolerant species in the trap nets (i.e., 81% Common Carp, Black Bullhead, and Bigmouth Buffalo) was high when compared to similar healthy lakes. The gill net metric score (i.e., 7% Channel Catfish, Northern Pike, and Black Crappie) was also below expectations for similar lakes. Six tolerant species, eight insectivorous species, two small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Johnny Darter, Pumpkinseed, and Spottail Shiner that positively affect several FIBI metric scores (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that several additional species have been sampled in Double Lake at various times

in the past. MNDNR fisheries surveys sampled Bluntnose Minnow in 1994, Brassy Minnow in 1994, Brook Stickleback in 1994, Common Shiner in 1995 and 1999, Creek Chub in 1995, Golden Redhorse in 1999, Quillback in 1995, River Redhorse in 2007, Stonecat in 2011, and Tadpole Madtom in 1986. These species have not been observed in more recent MNDNR surveys (MNDNR 2018c). These species may have been represented by only one or two occurrences and identification confirmation cannot occur due to the lack of vouchered specimens.

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to an impaired fish community in Double Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 93.6 ppb (N=8), chlorophyll-a is 33 ppb (N=8), and Secchi transparency is 2.6 feet (N=8) in Double Lake. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community. Additionally, Double Lake and one upstream water body, Bean Lake, were added to MPCA's impaired waters list for nutrients in 2010. Implementation strategies to address these nutrient impairments, which could also benefit the fish community in Double Lake, are outlined in the CRW Total Maximum Daily Load (TMDL; MPCA 2021d) and Watershed Restoration and Protection Strategies (WRAPS; MPCA 2021e) reports.

Of the 1,385 acres within the contributing watershed, 64.3% is classified as unnatural land cover (i.e., 59.8% agricultural, 4.2% developed, and 0.3% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Approximately 98% of the agricultural land is cultivated whereas 2% is hay and pasture land. Two active feedlots are also located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of Double Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also relatively low when compared to the size of Double Lake, as indicated by a watershed-to-lake ratio of 5.8:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

No Aquatic Management Areas (AMAs) or other state or federal lands are present within the contributing watershed; however, 37.8 acres of private land are protected through conservation easements established through the Minnesota Board of Water and Soil Resources (BWSR) Reinvest in Minnesota (RIM) Reserve program (BWSR 2021). Additionally, nearly 55 acres (i.e., 4% of Double Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Double Lake. Internal loading can be problematic, particularly in shallow lakes, due to

sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in Double Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Although residential shoreline development is low around Double Lake, as indicated by a dock density estimate of 2.7 docks per mile (7/22/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and may have contributed to shoreline habitat degradation and bank erosion in some areas (Figure 3). Replacement of riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Figure 3. Examples of bank erosion present around Double Lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural best management practices (BMPs), one effective way to protect shoreline habitat that may be vulnerable to disturbance is through acquisition of AMAs or RIM conservation easements; however, none currently exist along Double Lake's immediate shoreline.

The most recent aquatic plant surveys on Double Lake, 1995 and 2003 transect surveys, indicate that the lake does not support a diverse plant community (N=1; Sago Pondweed), resulting in a low floristic quality index (FQI; 3). These attributes indicate that fish habitat provided by aquatic plants may be lacking. The low diversity of aquatic plants present in Double Lake is likely the result of poor water clarity from eutrophication and associated algal blooms, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal may be lacking.

Common Carp, a non-native fish species, are present in Double Lake. Recent surveys indicate that Common Carp are sampled at a similar rate as other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in Double Lake has varied by 1.8 feet between 1961–1986 (MNDNR, unpublished data). An outlet structure is present on South Double Lake that contains a removable fish grate, installed by the Red Rock Sportsmen's Club due to the perception that game fish migrate out of the lake during times of outflow. Two culverts within the downstream watershed have been documented in the MNDNR Culvert Inventory that may act as potential barriers to fish passage at some flows. These culverts are located on Highwater Creek at County Road 5 and at a field crossing east of 400th Avenue. Aside from these two potential barriers and the removable fish grate, Double Lake connects to the Cottonwood River with no other impediments (A. Hillman, MNDNR, unpublished data). Should any of these structures act as barriers to fish passage, actions should be considered to restore connectivity, particularly during seasons when native fish movement into Double Lake is most likely to occur and while simultaneously considering risks associated with potential upstream movement of non-native species such as Bighead and Silver Carp via the Minnesota River.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Double Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp are present in Double Lake. Common Carp have the potential to displace other native fish species if they occur at high densities; however, within Double Lake, catch rates from recent trap net surveys would indicate that they are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Double Lake had been stocked with bullhead spp., crappie spp., Largemouth Bass, Northern Pike, sunfish spp., Walleye, White Crappie, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in two of every three years and Northern Pike fingerlings at 5–10 per littoral acre in one of every three years, as described in the 2017 lake management plan amendment (MNDNR, unpublished data). These stocking rates are within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Double Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Commercial removal of Common Carp, Bigmouth Buffalo, White Sucker, and Black Bullhead has occurred since the 1940's, but it is unlikely that removal of these tolerant and/or omnivorous species would negatively influence the fish community as measured by the FIBI.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Double Lake.

Double Lake occasionally experienced low winter dissolved oxygen levels until an aeration system was installed in 1984. Factors that may have contributed to low dissolved oxygen levels prior to that time likely included the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to an aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, even in aerated lakes. Additional research may be warranted to better understand fish community responses to aeration in lakes.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in Double Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

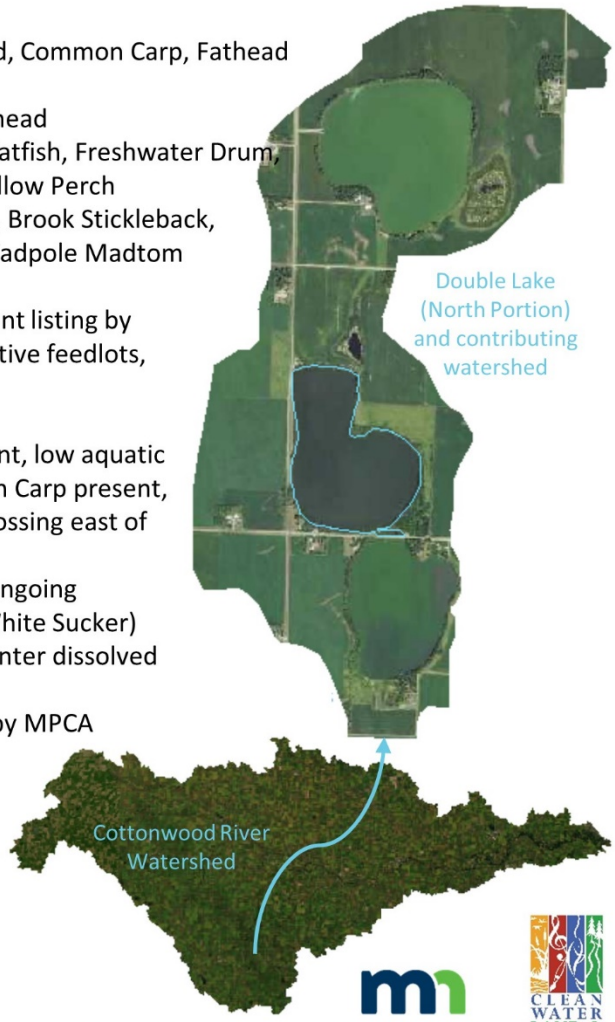
Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 58.4%) of Double Lake's contributing watershed is cultivated. Several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one CRW stream, Sleepy Eye Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Cottonwood River (e.g., clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Additional monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Double Lake, and any potential negative effects to the fish community that may be occurring as a result.

Double Lake (North Portion; 17-0056-01) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI score: 17 (19 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Bigmouth Buffalo, Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish, Orangespotted Sunfish
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Black Crappie, Bluegill, Channel Catfish, Freshwater Drum, Iowa Darter, Largemouth Bass, Northern Pike, Shorthead Redhorse, White Crappie, Yellow Perch
  - Other species that have previously been sampled: Bluntnose Minnow, Brassy Minnow, Brook Stickleback, Common Shiner, Creek Chub, Golden Redhorse, Quillback, River Redhorse, Stonecat, Tadpole Madtom
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 93.6 ppb mean total phosphorus, nutrient impairment listing by MPCA, 64% of contributing watershed classified as unnatural land cover including 2 active feedlots, small watershed-to-lake ratio of 5.8:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Low dock density of 2.7 docks per mile, bank erosion present, low aquatic plant diversity (eutrophication related), no non-native aquatic plants present, Common Carp present, fish grate present at outlet, culverts on Highwater Creek at County Road 5 and field crossing east of 400th Ave identified as potential fish barriers at some flows
  - Altered interspecific competition: Common Carp present, stocking activities present, ongoing commercial fish removal (i.e., Bigmouth Buffalo, Black Bullhead, Common Carp, and White Sucker)
  - Decreased dissolved oxygen: Winter aeration system present due to occasional low winter dissolved concentrations historically
  - Pesticide application: Chlorpyrifos levels exceed chronic standard, pesticide impaired by MPCA
- **Recommendations:**
  - Follow TMDL and WRAPS recommendations and continue to promote and implement agricultural BMP's within the Cottonwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Evaluate downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 4. Double Lake (North Portion; 17-0056-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

4.2. Rock Lake (DOW 42-0052-00)

Rock Lake is 379 acres in size and has a maximum depth of 8 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Rock Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Rock Lake and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, decreased dissolved oxygen, and pesticide application have been identified as inconclusive stressors (Figure 5). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Rock Lake was sampled using seining and backpack electrofishing during July 2014 and gill netting and trap netting during June 2014. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI score, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicates the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI score of 3 was below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Rock Lake.

During the 2015 FIBI survey, 13 fish species were captured (Table 5). All six species classified as tolerant in the FIBI (i.e., Bigmouth Buffalo, Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish, and Orangespotted Sunfish) were sampled. The proportion of biomass from insectivorous species in the trap nets (i.e., 2% Yellow Perch and Orangespotted Sunfish) and the gill net metric score (i.e., 5% Northern Pike and Channel Catfish) were below expectations for similar lakes as indicated by the respective FIBI metrics. Six tolerant species, five insectivorous species, one small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Bluegill, Freshwater Drum, Iowa Darter, Largemouth Bass, Pumpkinseed, Spottail Shiner, and White Crappie that positively affect several FIBI metric scores (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, MNDNR fisheries data indicates that one additional species, Bluegill, had been sampled in Rock Lake in 2002. Bluegill have not been observed in more recent MNDNR surveys (MNDNR 2018c).

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to an impaired fish community in Rock Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 238.8 ppb (N=5), chlorophyll-a is 25 ppb (N=5), and Secchi transparency is 2.3 feet (N=4) in Rock Lake. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community. Additionally, Rock Lake was added to MPCA's impaired waters list for nutrients in 2010. Implementation strategies to address this nutrient impairment, which could also benefit the fish community, are outlined in the CRW TMDL (MPCA 2021d) and WRAPS (MPCA 2021e) reports.

Of the 3,585 acres within the contributing watershed, 81.7% is classified as unnatural land cover (i.e., 78.1% agricultural, 3.4% developed, and 0.2% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Approximately 86% of the agricultural land is cultivated whereas 14% is hay and pasture land. Three active feedlots are also located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of Rock Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also moderate when compared to the size of Rock Lake, as indicated by a watershed-to-lake ratio of 9.5:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

Although a high percentage of land is classified as unnatural, several acres of one Wildlife Management Area, Rock Lake Marsh WMA, and several acres of RIM conservation easements (BWSR 2021) are located within the contributing watershed. Additionally, nearly 340 acres (i.e., 9% of Rock Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Rock Lake. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in Rock Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 72, is moderate for Rock Lake and just below the statewide average score of 73. While the shoreline and aquatic habitat components received high scores (i.e., 29 and 28 out of a possible 33.3, respectively), the shoreland habitat component received a very low score (i.e., 14). Although residential shoreline development is very low

around Rock Lake, as indicated by a dock density estimate of 1.6 docks per mile (7/22/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and has resulted in habitat degradation in some areas. Replacement of native riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural BMPs, one effective way to protect shoreline habitat that may be vulnerable to disturbance is through acquisition of AMAs, WMAs, or RIM conservation easements. A portion of Rock Lake Marsh WMA protects approximately 0.2 miles of shoreline on the southeast end of the lake from development.

The most recent aquatic plant surveys on Rock Lake, 1994 and 2006 transect surveys, indicate that the lake has had variable but low aquatic plant diversity (N=2–3; bulrush sp., Lesser Duckweed, and Common Reedgrass) and lacks submersed species, resulting in a relatively low FQI (6–8). A 1948 Department of Conservation survey listed several additional species such as Clasping-leaf Pondweed, Sago Pondweed, and Northern Watermilfoil. These attributes indicate that fish habitat provided by aquatic plants may be lacking, particularly in recent years. The low diversity of aquatic plants present in Rock Lake is likely the result of poor water clarity from eutrophication and associated algal blooms, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal are lacking.

Common Carp, a non-native fish species, are present in Rock Lake. Recent surveys indicate that Common Carp are sampled at a similar rate as other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in Rock Lake has varied by 4.9 feet between 1976–1998 (MNDNR, unpublished data). A crude rock dam is present at the outlet, which connects Rock Lake to the headwaters of the Cottonwood River. Several culverts within the downstream watershed have also been documented in the MNDNR Culvert Inventory that may act as potential barriers to fish passage at some flows. These culverts are located on the Cottonwood River where it crosses 140th Street, County Road 5, and U.S. 59 (A. Hillman, MNDNR, unpublished data). Additionally, two road crossings immediately downstream of Rock Lake have not been evaluated. These crossings, located on the Cottonwood River at 190th Avenue and 150th Street, should be investigated to determine their potential as barriers to fish passage. If these crossings or the other identified dam or crossings are determined to act as barriers, actions should be considered to restore connectivity for native fishes while simultaneously considering risks associated with potential upstream movement of non-native species such as Bighead and Silver Carp via the Minnesota River.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Rock Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp are present in Rock Lake. Common Carp have the potential to displace other native fish species if they occur at high densities; however, within Rock Lake, catch rates from recent trap net

surveys would indicate that they are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Rock Lake had been stocked with Black Crappie, Bluegill, Northern Pike, Largemouth Bass, Walleye, White Crappie, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in one of every two years, as described in the 2017 lake management plan amendment (MNDNR, unpublished data). This stocking rate is within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Rock Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Commercial removal of Common Carp and Black Bullhead has occurred since 1975, but it is unlikely that removal of these tolerant, omnivorous species would negatively influence the fish community as measured by the FIBI.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Rock Lake.

Rock Lake occasionally experienced low winter dissolved oxygen levels until an aeration system was installed in 1984. Factors that may have contributed to low dissolved oxygen levels prior to that time likely included the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to an aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, even in aerated lakes. Additional research may be warranted to better understand fish community responses to aeration in lakes.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in Rock Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

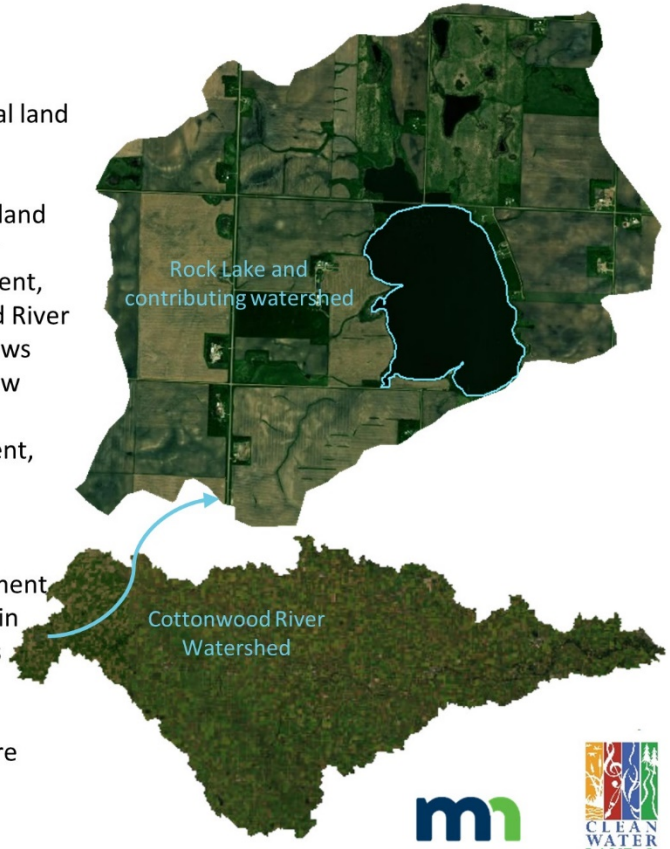
Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 67.3%) of Rock Lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within Rock Lake, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within the CRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one CRW stream, Sleepy Eye Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Cottonwood River (e.g., clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Rock Lake, and any potential negative effects to the fish community that may be occurring as a result.

Rock Lake (42-0052-00) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI score: 3 (33 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Bigmouth Buffalo, Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish, Orangespotted Sunfish
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker
  - Species sampled that positively affect the FIBI score: Black Crappie, Channel Catfish, Johnny Darter, Northern Pike, Yellow Perch
  - Other species that have previously been sampled: Bluegill
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 238.8 ppb mean total phosphorus, nutrient impairment listing by MPCA, 82% of contributing watershed classified as unnatural land cover including 3 active feedlots, moderate watershed-to-lake ratio of 9.5:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Moderate Score the Shore score of 72 (very low shoreland habitat quality, primarily agricultural), low dock density of 1.6 docks per mile, low aquatic plant diversity (eutrophication related), no non-native aquatic plants present, Common Carp present, crude rock dam present at outlet, culverts on Cottonwood River at 140th St, County Rd 5, and US 59 identified as potential fish barriers at some flows
  - Decreased dissolved oxygen: Winter aeration system present due to occasional low winter dissolved concentrations historically
  - Altered interspecific competition: Common Carp present, stocking activities present, occasional commercial fish removal (i.e., Black Bullhead and Common Carp)
  - Pesticide application: No data, pesticide impairments present in watershed
- **Recommendations:**
  - Follow TMDL and WRAPS recommendations and continue to promote and implement agricultural BMP's within the Cottonwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Evaluate downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 5. Rock Lake (42-0052-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

5. Evaluation of candidate causes in impaired and vulnerable lakes in the Redwood River Watershed

Four lakes in the RRW were assessed as not supporting aquatic life use because they had FIBI scores that were below the impairment threshold (Table 4). These lakes include Dead Coon (41-0021-01), Benton (41-0043-00), East Twin (42-0070-00), and Wood (42-0078-00). One additional lake, Island Lake (42-0096-00), was considered to have insufficient information to make an assessment decision based on a limited sampling history; however, it was considered vulnerable to future impairment (Table 4). Causes of stress to the fish communities in these impaired lakes are evaluated.

5.1. Dead Coon Lake (DOW 41-0021-01)

Dead Coon Lake is 547 acres in size and has a maximum depth of 9 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Dead Coon Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Dead Coon Lake and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, decreased dissolved oxygen, and pesticide application have been identified as inconclusive stressors (Figure 6). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Dead Coon Lake was sampled using seining and backpack electrofishing during August 2014 and July 2017 and gill netting and trap netting during June 2013 and July 2017. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI scores, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicate the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI scores of 5 in both 2014 and 2017 were below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Dead Coon Lake.

During the FIBI surveys, 10 fish species were captured (Table 5). The number of insectivorous species (i.e., Orangespotted Sunfish, Johnny Darter, and Yellow Perch), proportion of biomass from insectivorous species (i.e., <1% Yellow Perch) in the trap nets, and gill net metric score (i.e., 5 to 7% Northern Pike) were below expectations for similar lakes as indicated by the respective FIBI metrics. Four tolerant species, three insectivorous species, one small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Bluegill, Freshwater Drum, Iowa Darter, Largemouth Bass, Pumpkinseed, and Spottail Shiner that positively affect several FIBI metric scores and Bigmouth Buffalo and Green Sunfish that have the potential to negatively affect several FIBI metric scores but positively affect others (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that several additional species have been sampled in Dead Coon Lake at various times in the past. MNDNR fisheries surveys sampled Bluegill in 1983 and 1996, Brook Stickleback in 1996, Green Sunfish in 1983, Largemouth Bass in 1996, and Pumpkinseed in 1983. Likewise, J. F. Bell Museum surveys sampled Brook Stickleback and Iowa Darter in 1938 and both species had been vouchered. These species have not been observed in more recent surveys (MNDNR 2018c).

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to an impaired fish community in Dead Coon Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 142.1 ppb (N=8), chlorophyll-a is 19.6 ppb (N=8), and Secchi transparency is 2.3 feet (N=23) in Dead Coon Lake. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community. Additionally, Dead Coon Lake was added to MPCA's impaired waters list for nutrients in 2010. Similarly, one upstream water body, Lake Benton, was added to MPCA's impaired waters list for nutrients in 2006. Implementation strategies to address these nutrient impairments, which could also benefit the fish community in Dead Coon Lake, are outlined in the RRW TMDL (MPCA 2021f) and WRAPS (MPCA 2021g) reports.

Of the 47,006 acres within the contributing watershed, 73.4% is classified as unnatural land cover (i.e., 69.0% agricultural, 4.3% developed, and 0.1% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Approximately 97% of the agricultural land is cultivated whereas 3% is hay and pasture land. Fifty-five active feedlots are also located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of Dead Coon Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also high when compared to the size of Dead Coon Lake, as indicated by a watershed-to-lake ratio of 85.9:1. The combination of a relatively large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways.

Although a high percentage of land is classified as unnatural, several WMAs, Waterfowl Production Areas (WPAs), and RIM conservation easements (BWSR 2021) are located within the large contributing watershed. WMAs and WPAs include Collinson WMA, Coon Creek WPA, Chen Bay WMA, Dead Coon Marshes WMA, Fox WPA, Horse Slough WMA, Marshfield WMA, Sioux Lookout WMA, Two Sloughs WMA, Weber WPA, and Weeks WMA. Additionally, nearly 4,810 acres (i.e., 10% of Dead Coon Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Dead Coon Lake. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in Dead Coon Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 69, is moderate for Dead Coon Lake and below the statewide average score of 73. While the shoreline and aquatic habitat components received moderate scores (i.e., 27 and 27 out of a possible 33.3, respectively), the shoreland habitat component received a very low score (i.e., 15). Although residential shoreline development is very low around Dead Coon Lake, as indicated by a dock density estimate of 0.7 docks per mile (8/14/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and may have contributed to shoreline habitat degradation and bank erosion in some areas. Replacement of native riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural best management practices (BMPs), one effective way to protect shoreline habitat that may be vulnerable to disturbance is through acquisition of AMAs or RIM conservation easements; however, none currently exist along Dead Coon Lake's immediate shoreline.

The most recent aquatic plant surveys on Dead Coon Lake, a 2003 point intercept survey and a 2009 transect survey, indicate that the lake does not support a diverse plant community (N=1; Hardstem Bulrush) and lacks submersed species, resulting in a low FQI (5). These attributes indicate that fish habitat provided by aquatic plants may be lacking. The low diversity of aquatic plants present in Dead Coon Lake is likely the result of poor water clarity from eutrophication and associated algal blooms, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal may be lacking.

Common Carp, a non-native fish species, are present in Dead Coon Lake. Recent surveys indicate that Common Carp are sampled at a similar rate as other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in Dead Coon Lake has varied by 6.9 feet between 1960–1995 (MNDNR, unpublished data). Although numerous road crossings exist within the upstream and downstream watersheds of Dead Coon Lake, no culverts or crossings have been evaluated in the MNDNR Culvert Inventory.

However, several water control structures are present that would act as barriers to fish passage. One structure, located at the outlet of Lake Benton, is upstream of Dead Coon Lake whereas two structures, one located at the outlet of Dead Coon Lake and one below Coon Creek Marsh (42-0081-00), are downstream along Coon Creek prior to connection with the Redwood River (B. Swanson, MNDNR, personal communication). Aerial imagery indicates that several culverts exhibit perched or partially perched characteristics during some flows. These culverts, located upstream of Dead Coon Lake on Coon Creek at Highways 121, 13, 110, and 113, should be investigated to determine their potential as barriers to fish passage. If these culverts, the identified water control structures, or other crossings are determined to act as barriers, actions should be considered to restore connectivity for native fishes while simultaneously considering risks associated with potential upstream movement of non-native species such as Bighead and Silver Carp via the Minnesota River.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Dead Coon Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp are present in Dead Coon Lake. Common Carp have the potential to displace other native fish species if they occur at high densities; however, within Dead Coon Lake, catch rates from recent trap net surveys would indicate that they are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Dead Coon Lake had been stocked with Black Crappie, Bluegill, bullhead spp., Largemouth Bass, Northern Pike, Walleye, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in one of every two years and Northern Pike fingerlings at 10 per littoral acre in one of every three years, as described in the 2017 lake management plan amendment (MNDNR, unpublished data). These stocking rates are within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Dead Coon Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Commercial removal of Common Carp, Black Bullhead, and sucker spp. has occurred since 1925, but it is unlikely that removal of these tolerant and/or omnivorous species would negatively influence the fish community as measured by the FIBI.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Dead Coon Lake.

Dead Coon Lake occasionally experienced low winter dissolved oxygen levels until an aeration system was installed in 1983. Factors that may have contributed to low dissolved oxygen levels prior to that time likely included the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to an aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, even in aerated lakes. Additional research may be warranted to better understand fish community responses to aeration in lakes.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in Dead Coon Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 66.9%) of Dead Coon Lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within Dead Coon Lake, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within either the CRW or RRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one RRW stream, Three Mile Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Dead Coon Lake, and any potential negative effects to the fish community that may be occurring as a result.

Dead Coon Lake (41-0021-01) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI scores: 2 surveys, both scored 5 (31 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Black Bullhead, Common Carp, Fathead Minnow, Orangespotted Sunfish
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker
  - Species sampled that positively affect the FIBI score: Black Crappie, Johnny Darter, Northern Pike, Yellow Perch
  - Other species that have previously been sampled: Bluegill, Brook Stickleback, Green Sunfish, Iowa Darter, Largemouth Bass, Pumpkinseed
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 142.1 ppb mean total phosphorus, nutrient impairment listing by MPCA, 73% of contributing watershed classified as unnatural land cover including 55 active feedlots, large watershed-to-lake ratio of 85.9:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Moderate Score the Shore score of 69 (very low shoreland habitat quality, primarily agricultural), low dock density of 0.7 docks per mile, low aquatic plant diversity (eutrophication related), no non-native aquatic plants present, Common Carp present, outlet structures present on Lake Benton, Dead Coon Lake, and Coon Creek Marsh, culverts on Coon Creek at Hwys 121, 13, 110, and 114 identified as potential fish barriers at some flows
  - Altered interspecific competition: Common Carp present, stocking activities present, ongoing commercial fish removal (i.e., Black Bullhead, Common Carp, and sucker species)
  - Decreased dissolved oxygen: Winter aeration system present due to occasional low winter dissolved concentrations historically
  - Pesticide application: No data, pesticide impairments present in watershed
- **Recommendations:**
  - Follow TMDL and WRAPS recommendations and continue to promote and implement agricultural BMP's within the Redwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted

For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 6. Dead Coon Lake (41-0021-01) fish community and stressors; based on fish index of biological integrity (FIBI) results.

5.2. Lake Benton (DOW 41-0043-00)

Lake Benton is 2,699 acres in size and has a maximum depth of 9 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Lake Benton is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Lake Benton and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, and pesticide application have been identified as inconclusive stressors (Figure 7). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Lake Benton was sampled using seining, backpack electrofishing, gill netting, and trap netting during August 2011 and July 2017. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI scores, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicate the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI scores of 15 in 2011 and 12 in 2017 were below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Lake Benton.

During the FIBI surveys, 15 fish species were captured (Table 5). The proportion of biomass from insectivorous species (i.e., <1–6% Bluegill, Green Sunfish, and Yellow Perch) in the trap nets and the gill net metric score (i.e., 2% Northern Pike) were below expectations for similar lakes as indicated by the respective FIBI metrics. The proportion of biomass from tolerant species (i.e., 40–72% Black Bullhead, Common Carp, and Green Sunfish) in the trap nets was high when compared to similar healthy lakes. Five tolerant species, six insectivorous species, two small benthic-dwelling species, and two vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Freshwater Drum, Pumpkinseed, Spottail Shiner, and White Crappie that positively affect several FIBI metric scores and Bigmouth Buffalo that have the potential to negatively affect several FIBI metric scores but positively affect others (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that several additional species have been sampled in Lake Benton at various times in the past. MNDNR fisheries surveys sampled Channel Catfish in 1992, Pumpkinseed in 1983, and White Crappie in 2001 and 2005. These species have not been observed in more recent MNDNR surveys (MNDNR 2018c).

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to an impaired fish community in Lake Benton based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 197.8 ppb (N=13), chlorophyll-a is 72.5 ppb (N=13), and Secchi transparency is 3.0 feet (N=8) in Lake Benton. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community. Additionally, Lake Benton was added to MPCA's impaired waters list for nutrients in 2006. Implementation strategies to address this nutrient impairment, which could also benefit the fish community, are outlined in the RRW TMDL (MPCA 2021f) and WRAPS (MPCA 2021g) reports.

Of the 27,976 acres within the contributing watershed, 66.8% is classified as unnatural land cover (i.e., 62.1% agricultural, 4.6% developed, and 0.1% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Approximately 96% of the agricultural land is cultivated whereas 4% is hay and pasture land. Thirty active feedlots are also located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake. Residentially developed land within the contributing watershed is predominantly located along the shoreline of Lake Benton and in the City of Lake Benton. Individual sewage treatment systems on parcels surrounding the lake have been inventoried and most have been updated to compliance (R. Olsen, Lincoln County Environmental Office, personal communication). Therefore, discharge from failing individual sewage treatment systems is likely not a significant contributing factor; however, runoff from lawns could be contributing excess nutrients into the lake. The quantity of land within the contributing watershed is also moderate when compared to the size of Lake Benton, as indicated by a watershed-to-lake ratio of 10.4:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

Although a high percentage of land is classified as unnatural, several WMAs, WPAs, and RIM conservation easements (BWSR 2021) are located within the contributing watershed. WMAs and WPAs include Collinson WMA, Chen Bay WMA, Fox WPA, Horse Slough WMA, Sioux Lookout WMA, Two Sloughs WMA, Weber WPA, and Weeks WMA. Additionally, nearly 1,717 acres (i.e., 6% of Lake Benton's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Lake Benton. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in Lake Benton based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 65, is low for Lake Benton and below the statewide average score of 73. While the shoreline and aquatic habitat components received moderate scores (i.e., 22 and 27 out of a possible 33.3, respectively), the shoreland habitat component received a very low score (i.e., 16). Moderate levels of residential shoreline development, as indicated by a dock density estimate of 9.6 docks per mile (8/14/2015 Google Imagery), as well as relatively high agricultural land use adjacent to the shoreline, have resulted in habitat degradation in some areas. Replacement of native riparian vegetation with open lawns or cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to residential and agricultural BMPs, one effective way to protect shoreline habitat that may be vulnerable to disturbance is through acquisition of AMAs or RIM conservation easements. A portion of Benton Lake AMA protects approximately 0.4 miles of shoreline on the southeast end of the lake from development.

Aquatic plant surveys on Lake Benton indicate that the lake has had variable aquatic plant diversity (N=1–6; Curly-leaf Pondweed, Richardson's Pondweed, Sago Pondweed, Flat-stemmed Pondweed, bulrush sp., Horned Pondweed, and Coontail), resulting in a variable but relatively low FQI (3–12). The most recent point-intercept survey indicates that 58% of surveyed points had non-native Curly-leaf Pondweed, 12% had native plants, and 36% had no plants (MNDNR 2018d). These attributes indicate that Curly-leaf Pondweed in particular is distributed throughout much of the lake; however, native plant diversity and distribution are lacking, particularly when compared to historic records (MNDNR 2018d). Although Curly-leaf Pondweed is a non-native submersed plant, it may still provide habitat for various vegetation-dependent game and non-game fishes given the low diversity and distribution of other native submersed aquatic plants currently found within the lake (Valley et al. 2004).

According to MPARS, no individual properties have been permitted to remove aquatic plants; however, lakewide fluridone treatments and partial lake endothall and fluridone treatments have previously occurred in an effort to reduce Curly-leaf Pondweed density. The lake vegetation management plan has also authorized a variance to treat Curly-leaf Pondweed at or beyond the 15% littoral limit, provided that no negative impacts to water quality or native vegetation occur as a result.

Common Carp, a non-native fish species, are present in Lake Benton. Recent surveys indicate that Common Carp are sampled at a higher rate than in other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in Lake Benton has varied by 6.0 feet between 1947–2019 (MNDNR, unpublished data). Although numerous road crossings exist within the upstream and downstream watersheds of Lake Benton, no culverts or crossings have been evaluated in the MNDNR Culvert Inventory. However, several water control structures are present that would act as barriers to fish passage. Three structures, one located at the outlet of Lake Benton, one at the outlet of Dead Coon Lake, and one below Coon Creek Marsh (42-0081-00), are downstream along Coon Creek prior to connection with the Redwood River (B. Swanson, MNDNR, personal communication). Aerial imagery indicates that several culverts exhibit perched or partially perched characteristics during some flows. These culverts, located downstream on Coon Creek at Highways 121, 13, 110, and 113, should be investigated to determine their potential as barriers to fish passage. If these culverts, the identified water control structures, or other crossings are determined to act as barriers, actions should be considered to restore connectivity for native fishes while simultaneously considering risks associated with potential upstream movement of non-native species such as Bighead and Silver Carp via the Minnesota River.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Lake Benton based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp, which have the potential to displace other native fish species if they occur at high densities, are present in Lake Benton. Common Carp catch rates from recent trap net and gill net surveys indicate that the species is occurring at densities that exceed the interquartile range for lakes in the same lake class (MNDNR, unpublished data).

Historically, Lake Benton had been stocked with Black Crappie, Bluegill, bullhead spp., Largemouth Bass, Northern Pike, sucker spp., Walleye, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in one of every two years, as described in the 2018 lake management plan (MNDNR, unpublished data). These stocking rates are within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest were quantified for Lake Benton during the 1996 open water season and the 1996–1997 winter season due to the lake's importance as a regional fishing destination. Total estimated fishing pressure was 13.4 angler hours/acre, which was comparable to that found statewide for lakes less than 100,000 acres (Schultz and Sledge 1997). In addition to average angler effort, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Commercial removal of Black Bullhead and Common Carp has occurred as recently as 2008, and it is unlikely that removal of this tolerant, omnivorous species would negatively influence the fish community as measured by the FIBI.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Lake Benton.

Lake Benton occasionally experienced low winter dissolved oxygen levels until an aeration system was installed in 1980. Factors that may have contributed to low dissolved oxygen levels prior to that time likely included the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to an aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, even in aerated lakes. Additional research may be warranted to better understand fish community responses to aeration in lakes.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in Lake Benton; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

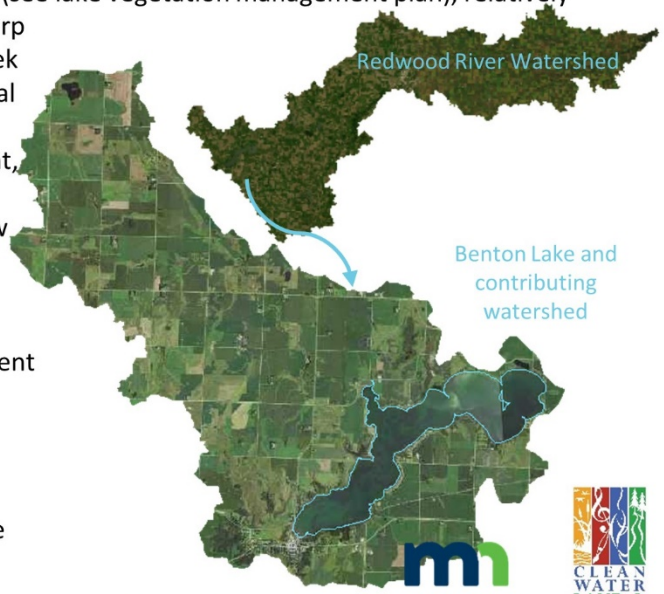
Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 59.5%) of Lake Benton's contributing watershed is cultivated. Although pesticide monitoring has not occurred within Lake Benton, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within either the CRW or RRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one RRW stream, Three Mile Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Lake Benton, and any potential negative effects to the fish community that may be occurring as a result.

Lake Benton (41-0043-00) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI scores: 2 surveys, scores of 15 and 12 (21 and 24 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Black Bullhead, Common Carp, Fathead Minnow, Green and Orangespotted Sunfish
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker
  - Species sampled that positively affect the FIBI score: Black Crappie, Bluegill, Brook Stickleback, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Yellow Perch
  - Other species that have previously been sampled: Channel Catfish, Pumpkinseed, White Crappie
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 197.8 ppb mean total phosphorus, nutrient impairment listing by MPCA, 67% of contributing watershed classified as unnatural land cover including 30 active feedlots, most septic systems updated to compliance, moderate watershed-to-lake ratio of 10.4:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Low Score the Shore score of 65 (very low shoreland habitat quality), moderate dock density of 9.6 docks per mile, whole and partial lake herbicide permits issued to treat Curly-leaf Pondweed (see lake vegetation management plan), relatively aquatic plant diversity but wide distribution, Curly-leaf Pondweed and Common Carp present, outlet structures present on Lake Benton, Dead Coon Lake, and Coon Creek Marsh, culverts on Coon Creek at Hwys 121, 13, 110, and 114 identified as potential fish barriers at some flows
  - Altered interspecific competition: Common carp present, stocking activities present, occasional commercial fish removal (i.e., Black Bullhead)
  - Decreased dissolved oxygen: Winter aeration system present due to occasional low winter dissolved concentrations historically
  - Pesticide application: No data, pesticide impairments present in watershed
- **Recommendations:**
  - Follow TMDL and WRAPS recommendations and continue to promote and implement agricultural BMP's within the Redwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Evaluate downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

Figure 7. Lake Benton (41-0043-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

5.3. East Twin Lake (DOW 42-0070-00)

East Twin Lake was 356 acres in size and had a maximum depth of 25 feet when last mapped in 2012; however water levels have increased by more than five feet since that time and were historically much lower. The littoral area of the lake has also decreased with the increasing water levels. Given these characteristics, the fish community in East Twin Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1). Although East Twin Lake currently has less than 80% littoral area, historically lower water levels and geographic location indicate that FIBI tool 7 is the most suitable tool for assessing the fish community in the lake, as these factors have likely shaped the present day fish community.

Eutrophication has been identified as a likely stressor to aquatic life in East Twin Lake and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, and pesticide application have been identified as inconclusive stressors (Figure 9). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in East Twin Lake was sampled using seining, backpack electrofishing, gill netting, and trap netting during two surveys in June 2016. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI scores, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicate the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI scores of 13 and 14 were below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to East Twin Lake.

During the FIBI surveys, nine fish species were captured (Table 5). The number of insectivorous species (i.e., Bluegill, Iowa Darter, and Yellow Perch), proportion of biomass from insectivorous species in the trap nets (i.e., 8% Bluegill and Yellow Perch), and gill net metric score (i.e., <1% Black Crappie) were below expectations for similar lakes as indicated by the respective FIBI metrics. Two tolerant species, three insectivorous species, one small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Freshwater Drum, Johnny Darter, Largemouth Bass, Northern Pike, Pumpkinseed, Spottail Shiner, and White Crappie that positively affect several FIBI metric scores, Bigmouth Buffalo and Green Sunfish that have the potential to negatively affect several FIBI metric scores but positively affect others, and Fathead Minnow that negatively affect several FIBI metric scores (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that several additional species have been sampled in East Twin Lake at various times in the past. MNDNR fisheries surveys sampled Channel Catfish in 2000, 2008, and 2012, Fathead Minnow in 1996 and 2000, Northern Pike in 1992, and Orangespotted Sunfish in 1992, 1996, and 2000. These species have not been observed in more recent MNDNR surveys (MNDNR 2018c).

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication has occurred, and is likely still occurring, at a level that would contribute to an impaired fish community in East Twin Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 37.4 ppb (N=9), chlorophyll-a is 11.5 ppb (N=9), and Secchi transparency is 7.9 feet (N=12) in East Twin Lake. Long-term Secchi transparency measurements indicate increasing water clarity, which may also coincide with increasing water levels. These parameters indicate that water quality may be improving but that the lake still has relatively high nutrient levels that could negatively affect the fish community. If poor water quality had reduced species richness historically, the lack of natural connectivity to other source populations may limit fish species recolonization, and thereby limit potential for improvement in future FIBI scores, even if water quality has been improving within the lake.

Of the 870 acres within the contributing watershed, 49.8% is classified as unnatural land cover (i.e., 48.7% agricultural, 1.0% developed, and 0.1% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Nearly all of the agricultural land is cultivated and no active feedlots are located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of East Twin Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also relatively low when compared to the size of East Twin Lake, as indicated by a watershed-to-lake ratio of 2.4:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

No AMAs or other state or federal lands are present within the contributing watershed; however, 10.5 acres of private land are protected through RIM conservation easements (BWSR 2021). Further, nearly 24 acres (i.e., 3% of East Twin Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the nutrients levels observed in East Twin Lake. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence. However, unlike for other lakes in the RRW, the increased depth of East Twin Lake may facilitate stratification and thus reduce potential impacts of internal loading.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in East Twin Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 66, is moderate for East Twin Lake and below the statewide average score of 73. While the shoreline and aquatic habitat components received moderate to high scores (i.e., 23 and 31 out of a possible 33.3, respectively), the shoreland habitat component received a very low score (i.e., 12). Although residential shoreline development is very low around East Twin Lake, as indicated by a dock density estimate of 0.4 docks per mile (8/14/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and may have contributed to shoreline habitat degradation and bank erosion in some areas (Figure 8). Replacement of native riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake. Recent high water levels are also exacerbating bank erosion and other shoreline habitat concerns.

Figure 8. Examples of bank erosion present around East Twin Lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural BMPs, one effective way to protect shoreline habitat that may be vulnerable to disturbance is through acquisition of AMAs or RIM conservation easements; however, none currently exist along East Twin Lake's immediate shoreline.

The most recent aquatic plant survey on East Twin Lake, a 1996 transect survey, indicates that the lake has relatively low aquatic plant diversity (N=3; narrowleaf pondweed sp., Richardson's Pondweed, and Sago Pondweed), resulting in a relatively low FQI (9). A 1948 Department of Conservation survey listed several additional species such as bulrush spp., Coontail, Clasping-leaf Pondweed, and Northern Watermilfoil. These attributes indicate that fish habitat provided by aquatic plants may be lacking, particularly in recent years. The low diversity of aquatic plants present in East Twin Lake is likely the combined result of poor water clarity from eutrophication historically and high water levels and

sedimentation from shoreline erosion presently, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal may be lacking.

Common Carp, a non-native fish species, are present in East Twin Lake. Recent surveys indicate that Common Carp are sampled at a similar rate as other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in East Twin Lake has increased by 12.1 feet between 2005–2020 (MNDNR, unpublished data). No significant inlets or outlets exist within the contributing watershed, therefore no dams, bridges, or culverts have been identified as potential barriers to fish passage. Although no artificial barriers have been identified, the natural lack of connectivity within the watershed could have a negative effect on species richness in East Twin Lake and therefore the FIBI score.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in East Twin Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp are present in East Twin Lake. Common Carp have the potential to displace other native fish species if they occur at high densities; however, within East Twin Lake, catch rates from recent trap net surveys would indicate that they are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, East Twin Lake had been stocked with Black Crappie, Bluegill, bullhead spp., Channel Catfish, Northern Pike, Smallmouth Bass, Walleye, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in two of every three years, as described in the 2017 lake management plan amendment (MNDNR, unpublished data). This stocking rate is within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for East Twin Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Commercial removal of Common Carp and Black Bullhead has occurred as recently as 1992, and it is unlikely that removal of these tolerant, omnivorous species would negatively influence the fish community as measured by the FIBI.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in East Twin Lake.

East Twin Lake occasionally experienced low winter dissolved oxygen levels until an aeration system was installed in 1988. Factors that may have contributed to low dissolved oxygen levels prior to that time likely included the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, recently collected data on several Minnesota waterbodies indicates that these levels may occur only within close proximity to an aerator. These observations indicate that conditions may be more favorable for species that are tolerant of low dissolved oxygen levels, even in aerated lakes. Additional research may be warranted to better understand fish community responses to aeration in lakes.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in East Twin Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 48.7%) of East Twin Lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within East Twin Lake, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within either the CRW or RRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one RRW stream, Three Mile Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in East Twin Lake, and any potential negative effects to the fish community that may be occurring as a result.

East Twin Lake (42-0070-00) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI scores: 13, 14 (23, 22 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Black Bullhead, Common Carp
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker
  - Species sampled that positively affect the FIBI score: Black Crappie, Bluegill, Iowa Darter, Smallmouth Bass, Yellow Perch
  - Other species that have previously been sampled: Channel Catfish, Fathead Minnow, Northern Pike
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 37.4 ppb mean total phosphorus, 50% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 2.4:1, increasing water clarity trend that coincides with increasing water levels
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Moderate Score the Shore score of 66 (very low shoreland habitat quality, primarily agricultural), low dock density of 0.4 docks per mile, bank erosion present, low aquatic plant diversity (eutrophication and/or water level related), no non-native aquatic plants present, Common Carp present, no inlet or outlet
  - Altered interspecific competition: Common Carp present, stocking activities present
  - Decreased dissolved oxygen: Winter aeration system present due to occasional low winter dissolved concentrations historically
  - Pesticide application: No data, pesticide impairments present in watershed
- **Recommendations:**
  - Follow WRAPS recommendations and continue to promote and implement agricultural BMP's within the Redwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Natural lack of connectivity, historic partial winterkill events, and current high water levels could be influencing the fish community

For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 9. East Twin Lake (42-0070-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

5.4. Wood Lake (DOW 42-0078-00)

Wood Lake is 373 acres in size and has a maximum depth of 14 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Wood Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Wood Lake and will be evaluated further. Conversely, physical habitat alteration, altered interspecific competition, and pesticide application have been identified as inconclusive stressors (Figure 10). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Wood Lake was sampled using seining, backpack electrofishing, gill netting, and trap netting during surveys in July 2012 and June 2016. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI scores, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicate the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI scores of 16 and 4 were below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Wood Lake.

During the FIBI surveys, 11 fish species were captured (Table 5). The proportion of biomass from insectivorous species (i.e., 1–4% Bluegill and Yellow Perch) in the trap nets and the gill net metric score (i.e., <1% Largemouth Bass) were below expectations for similar lakes as indicated by the respective FIBI metrics. The proportion of biomass from tolerant species (i.e., 82–86% Black Bullhead and Common Carp) in the trap nets was high when compared to similar healthy lakes. Four tolerant species, five insectivorous species, two small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Black Crappie, Freshwater Drum, Northern Pike, Pumpkinseed, Spottail Shiner, and White Crappie that positively affect several FIBI metric scores and Bigmouth Buffalo that have the potential to negatively affect several FIBI metric scores but positively affect others (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that several additional species have been sampled in Wood Lake at various times in the past. MNDNR fisheries surveys sampled Brook Stickleback in 1996 and Northern Pike in 1988. These species have not been observed in more recent MNDNR surveys (MNDNR 2018c).

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to an impaired fish community in Wood Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 167.6 ppb (N=8), chlorophyll-a is 23.3 ppb (N=8), and Secchi transparency is 3.3 feet (N=8) in Wood Lake. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community.

Of the 1,219 acres within the contributing watershed, 65.6% is classified as unnatural land cover (i.e., 61.7% agricultural and 3.9% developed; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Nearly all of the agricultural land is cultivated and no active feedlots are located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of Wood Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also relatively low when compared to the size of Wood Lake, as indicated by a watershed-to-lake ratio of 3.3:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

No AMAs or other state or federal lands are present within the contributing watershed and no private lands are protected through RIM conservation easements (BWSR 2021). However, nearly 99 acres (i.e., 8% of Wood Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in Wood Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 58, is low for Wood Lake and below the statewide average score of 73. While aquatic habitat component received a high score (i.e., 27 out of a possible 33.3), the shoreline and shoreland habitat components received low to very low scores (i.e., 21 and 9, respectively). Although residential shoreline development is very low around Wood Lake, as indicated by a dock density estimate of 1.1 docks per mile (8/14/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and has resulted in habitat degradation in some areas. Replacement of native riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural BMPs, one effective way to protect shoreline habitat that is vulnerable to disturbance is through acquisition of

AMAs or RIM conservation easements; however, none currently exist along Wood Lake's immediate shoreline.

The most recent aquatic plant survey on Wood Lake, a 1996 transect survey, indicates that the lake has relatively low aquatic plant diversity (N=5; Northern Watermilfoil, Richardson's Pondweed, Sago Pondweed, River Bulrush, and bulrush sp.), resulting in a relatively low FQI (12). A 1948 Department of Conservation survey listed several additional species such as Coontail. These attributes indicate that fish habitat provided by aquatic plants may be lacking, particularly in recent years. The relatively low diversity of aquatic plants present in Wood Lake is likely the result of poor water clarity from eutrophication and associated algal blooms, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal may be lacking.

Common Carp, a non-native fish species, are present in Wood Lake. Recent surveys indicate that Common Carp are sampled at a higher rate than in other lakes in the same lake class; however, any potential effects of the species have not been evaluated or documented (MNDNR, unpublished data). When occurring at high densities, Common Carp foraging behaviors can contribute to nutrient resuspension, low water clarity, and low plant diversity.

The water level in Wood Lake has varied by 11.5 feet between 1963–2019 (MNDNR, unpublished data). No significant inlets or outlets exist within the contributing watershed, therefore no dams, bridges, or culverts have been identified as potential barriers to fish passage. Although no artificial barriers have been identified, the natural lack of connectivity within the watershed could have a negative effect on species richness in Wood Lake and therefore the FIBI score.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Wood Lake. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Wood Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities; however, evidence is inconclusive.

Common Carp, which have the potential to displace other native fish species if they occur at high densities, are present in Wood Lake. Common Carp catch rates from recent trap net and gill net surveys are variable but indicate that the species is occasionally occurring at densities that exceed the interquartile range for lakes in the same lake class (MNDNR, unpublished data).

Historically, Wood Lake had been stocked with Black Crappie, Bluegill, Largemouth Bass, Northern Pike, Walleye, and Yellow Perch. MNDNR Fisheries currently stocks Walleye fry at a rate of 500 per littoral acre in one of every two years, as described in the 2017 lake management plan amendment (MNDNR, unpublished data). This stocking rate is within the normal range used by MNDNR Fisheries. No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes

are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Wood Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Similarly, no commercial fish removal has occurred.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Wood Lake.

Wood Lake has occasionally experienced low winter dissolved oxygen levels. Factors that may have contributed to these observations likely include the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, conditions may be more favorable for species that are tolerant of low dissolved oxygen levels.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the impaired fish community in Wood Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

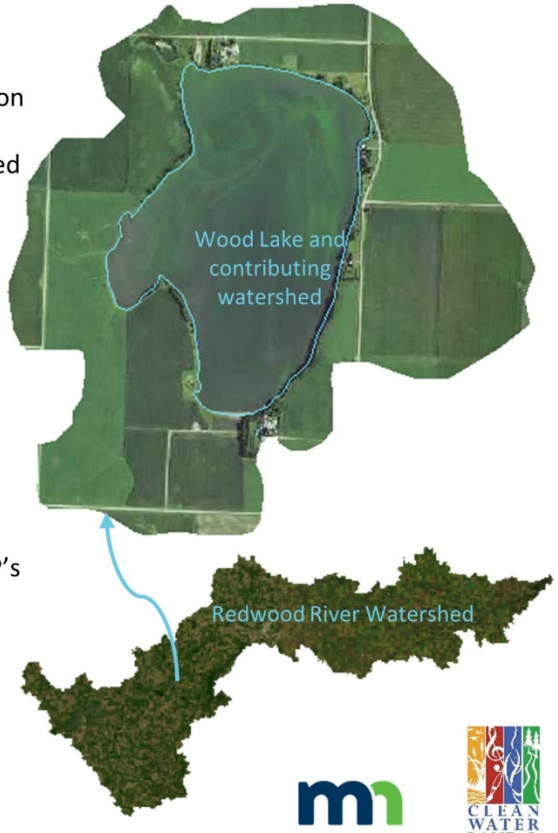
Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 61.4%) of Wood Lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within Wood Lake, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within either the CRW or RRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one RRW stream, Three Mile Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Wood Lake, and any potential negative effects to the fish community that may be occurring as a result.

Wood Lake (42-0078-00) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI scores: 16, 4 (32 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish
  - Species sampled that are neutral to the FIBI score: Walleye, White Sucker
  - Species sampled that positively affect the FIBI score: Bluegill, Iowa Darter, Johnny Darter, Largemouth Bass, Yellow Perch
  - Other species that have previously been sampled: Brook Stickleback, Northern Pike
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 167.6 ppb mean total phosphorus, inconclusive information to make nutrient impairment determination by MPCA (mean total phosphorus exceeded threshold but response variables were inconclusive), 66% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 3.3:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Low Score the Shore score of 58 (very low shoreland habitat quality, primarily agricultural), low dock density of 1.2 docks per mile, bank erosion present, low aquatic plant diversity (eutrophication related), no non-native aquatic plants present, Common Carp present, no inlet or outlet
  - Altered interspecific competition: Common Carp present, stocking activities present
  - Decreased dissolved oxygen: Occasionally observed low winter dissolved oxygen concentrations
  - Pesticide application: No data, pesticide impairments present in watershed
- **Recommendations:**
  - Follow WRAPS recommendations and continue to promote and implement agricultural BMP's within the Redwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Natural lack of connectivity could be influencing the fish community



For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 10. Wood Lake (42-0078-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

5.5. Island Lake (DOW 42-0096-00)

Island Lake is 170 acres in size and has a maximum depth of 8 feet. The littoral zone encompasses the entire lake area. Given these characteristics, the fish community in Island Lake is evaluated using FIBI tool 7. Lakes evaluated with this tool are characterized as generally shallow with greater than 80% littoral area and moderate species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life in Island Lake and will be evaluated further. Conversely, physical habitat alteration and pesticide application have been identified as inconclusive stressors and altered interspecific competition has been eliminated as a primary stressor (Figure 11). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Island Lake was sampled using seining and backpack electrofishing in June 2018 and gill netting and trap netting in July 2017. The health of the fish community was evaluated using these data and FIBI tool 7. The FIBI uses fish community data to measure a lake's health, and the types of fish species present can help identify any stressors that may be negatively affecting the lake environment. The FIBI score, composed of eight fish community diversity and composition metrics for tool 7 lakes (Table 1), indicates the overall health of a lake by comparing it to what is expected for a healthy lake. The FIBI score of 13 was below the impairment threshold (36) and lower confidence limit (27) developed for lakes that are similar to Island Lake.

During the FIBI surveys, six fish species were captured (Table 5). The number of insectivorous species (i.e., Green Sunfish and Yellow Perch), proportion of biomass from insectivorous species in the trap nets (i.e., 1% Green Sunfish and Yellow Perch), and gill net metric score (i.e., 11% Northern Pike) were below expectations for similar lakes as indicated by the respective FIBI metrics. Three tolerant species, two insectivorous species, no small benthic-dwelling species, and one vegetation-dwelling species were sampled. Examples of other species sampled in similar lakes within the Minnesota River Basin that contain healthy fish communities as indicated by FIBI tool 7 include Black Crappie, Bluegill, Freshwater Drum, Iowa Darter, Johnny Darter, Largemouth Bass, Pumpkinseed, Spottail Shiner, and White Crappie that positively affect several FIBI metric scores, Bigmouth Buffalo that have the potential to negatively affect several FIBI metric scores but positively affect others, and Common Carp that negatively affect several FIBI metric scores (Table 5).

Because this is the first time utilizing FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that at least one additional species, Iowa Darter, had been sampled in Island Lake in 1999. This species has not been observed in more recent MNDNR surveys (MNDNR 2018c) and identification confirmation cannot occur due to the lack of vouchered specimens.

Data analysis/evaluation for each candidate cause

Eutrophication

Eutrophication is likely occurring at a level that would contribute to a vulnerable fish community in Island Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA during watershed assessment indicates that mean summer TP is 122.5 ppb (N=8), chlorophyll-a is 133.8 ppb (N=8), and Secchi transparency is 1.6 feet (N=8) in Island Lake. These parameters indicate that the lake has high nutrient levels that could negatively affect the fish community. Additionally, Island Lake was added to MPCA's impaired waters list for nutrients in 2020. Implementation strategies to address this nutrient impairment, which could also benefit the fish community, are outlined in the RRW TMDL (MPCA 2021f) and WRAPS (MPCA 2021g) reports.

Of the 1,088 acres within the contributing watershed, 78.3% is classified as unnatural land cover (i.e., 74.6% agricultural, 3.4% developed, and 0.3% barren; MNDNR 2018b). The percentage of unnatural land cover exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). Approximately 72% of the agricultural land is cultivated whereas 28% is hay and pasture land. One active feedlot is also located within the contributing watershed (MPCA 2021c). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake. Conversely, residentially developed land is minimal both within the contributing watershed and along the shoreline of Island Lake. As such, runoff from lawns and discharge from failing individual sewage treatment systems are unlikely contributors of excess nutrients. The quantity of land within the contributing watershed is also relatively low when compared to the size of Island Lake, as indicated by a watershed-to-lake ratio of 6.4:1, therefore management actions intended to reduce excess nutrient inputs may be relatively targeted and reasonably attainable.

No AMAs or other state or federal lands are present within the contributing watershed and no private lands are protected through RIM conservation easements (BWSR 2021). However, nearly 57 acres (i.e., 5% of Island Lake's contributing watershed) have been identified as drained or partially drained wetlands that could be restored (Ducks Unlimited 2014). Undeveloped or restored lands, particularly those that are protected from future development, play a critical role in collecting and filtering rainfall, recharging the groundwater supply, and reducing surface runoff that could otherwise be contributing sediment and nutrients into lakes and rivers.

In addition to watershed disturbance, internal loading may be a source of the high nutrients levels observed in Island Lake. Internal loading can be problematic, particularly in shallow lakes, due to sediment phosphorus release that can occur through several mechanisms including wind resuspension and bioturbation, periodic anoxia, and/or plant senescence.

Information about select inconclusive and eliminated causes

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to a vulnerable fish community in Island Lake based on review of information reflecting riparian disturbance, aquatic plant community condition, non-native species introduction, water level management, and connectivity; however, evidence is inconclusive.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 67, is moderate for Island Lake and below the statewide average score of 73. While the shoreline and aquatic habitat components received moderate to high scores (i.e., 22 and 31 out of a possible 33.3, respectively), the shoreland habitat component received a very low score (i.e., 13). Although residential shoreline development is very low around Island Lake, as indicated by a dock density estimate of 0.4 docks per mile (8/14/2015 Google Imagery), agricultural land use adjacent to the shoreline is relatively high and has resulted in habitat degradation in some areas. Replacement of native riparian vegetation with cultivated crops can result in increased nutrient inputs from fertilizer, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into a lake.

Just as removal of riparian vegetation can negatively affect shoreline habitat, establishment of riparian buffers can play a critical role protecting or improving shoreline habitat. In addition to agricultural BMPs, one effective way to protect shoreline habitat that is vulnerable to disturbance is through acquisition of AMAs or RIM conservation easements; however, none currently exist along Island Lake's immediate shoreline.

The most recent aquatic plant survey on Island Lake, a 1999 transect survey, indicates that the lake has relatively low aquatic plant diversity (N=6; chara sp., duckweed sp., Richardson's Pondweed, Sago Pondweed, River Bulrush, and bulrush sp.), resulting in a relatively low FQI (12). A 1948 Department of Conservation survey listed several additional species such as Clasping-leaf Pondweed, Narrowleaf Pondweed, and Coontail. These attributes indicate that fish habitat provided by aquatic plants may be somewhat lacking, particularly in recent years. The relatively low diversity of aquatic plants present in Island Lake is likely the result of poor water clarity from eutrophication and associated algal blooms, rather than the result of physical plant removal by lakeshore owners, which is generally more of a concern in lakes with much higher residential development. Further, no properties have been permitted to remove aquatic plants according to MPARS, but data for other sources of removal may be lacking.

No non-native fish or plant species have been documented in Island Lake. Similarly, no significant inlets or outlets exist within Island Lake's contributing watershed, therefore no dams, bridges, or culverts have been identified as potential barriers to fish passage. Although no artificial barriers have been identified, the natural lack of connectivity within the watershed could have a negative effect on species richness in Island Lake and therefore the FIBI score.

Altered interspecific competition

Altered interspecific competition is not likely occurring at a level that would contribute to the vulnerable fish community in Island Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities.

Common Carp, which have the potential to displace other native fish species if they occur at high densities, have not been documented in Island Lake.

Historically, Island Lake had been stocked with Northern Pike according to the 2011 lake management plan; however, stocking has not occurred since 2016 (MNDNR, unpublished data). No significant relationships between FIBI scores or metrics and the number of species stocked, relative abundance of stocked species, or Walleye stocking density have been observed in Minnesota lakes (Drake and Pereira 2002; J. Bacigalupi, MNDNR, unpublished data). However, effects in individual lakes are possible as management activities can vary considerably based on individual lake characteristics and communities.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Island Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Regardless, no special regulations have been implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Similarly, no commercial fish removal has occurred.

Decreased dissolved oxygen

Although dissolved oxygen monitoring and a lack of observed winterkill would indicate that dissolved oxygen is currently sufficient, decreased dissolved oxygen is considered an inconclusive stressor to the fish community in Island Lake.

Island Lake has occasionally experienced low winter dissolved oxygen levels. Factors that may have contributed to these observations likely include the lake's shallow depth, small size, and productivity resulting from excess nutrient inputs. Although limited monitoring indicates that winter dissolved oxygen levels are currently sufficient, conditions may be more favorable for species that are tolerant of low dissolved oxygen levels.

Pesticide application

Pesticide application may be occurring at a level that would contribute to the vulnerable fish community in Island Lake; however, a lack of adequate data makes it difficult to provide evidence that pesticides are a source of impairment.

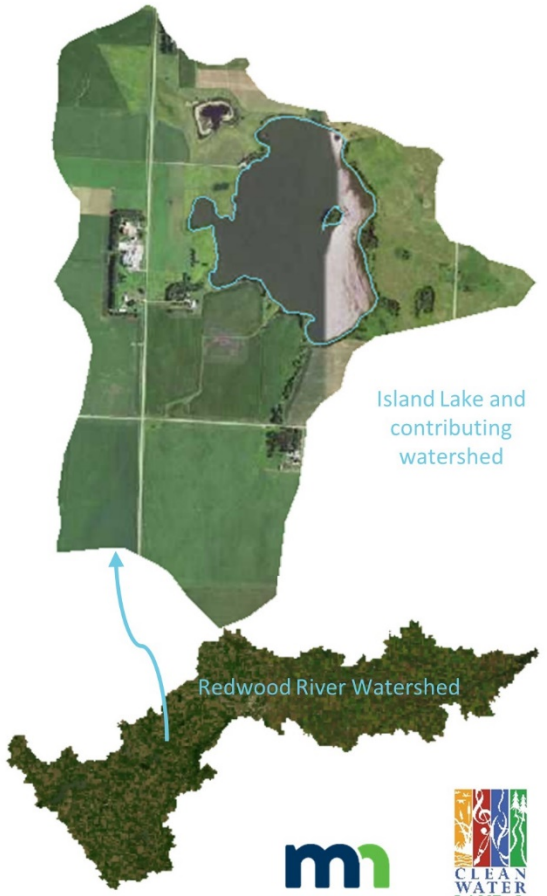
Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion (i.e., 66.9%) of Island Lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within Island Lake, several pesticides, including fomesafen and chlorpyrifos, were detected in Double Lake, the only monitored lake within either the CRW or RRW, during MDA surface water pesticide monitoring (MDA 2018). Chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Pesticide monitoring has also resulted in the designation of one RRW stream, Three Mile Creek, as impaired for chlorpyrifos (MPCA 2020a). Other pesticide detections exceeding chronic standards or USEPA Office of Pesticide Programs benchmark values also occurred in the Redwood River (e.g., acetochlor, clothianidin, imidacloprid, and chlorpyrifos; MDA 2018).

Monitoring may be warranted to evaluate the extent of pesticide use within the contributing watershed, the number of pesticides and total concentration present in Island Lake, and any potential negative effects to the fish community that may be occurring as a result.

Island Lake (42-0096-00) fish community and stressors; based on fish index of biological integrity (FIBI) results

- **Fish community:**
  - FIBI score: 13 (23 points below impairment threshold)
  - Species sampled that negatively affect the FIBI score: Black Bullhead, Fathead Minnow, Green Sunfish
  - Species sampled that are neutral to the FIBI score: Brown Bullhead
  - Species sampled that positively affect the FIBI score: Northern Pike, Yellow Perch
  - Other species that have previously been sampled: Iowa Darter
- **Candidate causes of fish IBI impairment:**
  - Eutrophication (excess nutrients): 122.5 ppb mean total phosphorus, nutrient impairment listing by MPCA, 78% of contributing watershed classified as unnatural land cover including 1 active feedlot, small watershed-to-lake ratio of 6.4:1
- **Inconclusive causes of fish IBI impairment:**
  - Physical habitat alteration: Moderate Score the Shore score of 67 (very low shoreland habitat quality, primarily agricultural), low dock density of 0.4 docks per mile, bank erosion present, low aquatic plant diversity (eutrophication related), no non-native species present, no inlet or outlet
  - Decreased dissolved oxygen: Occasionally observed low winter dissolved oxygen concentrations
  - Pesticide application: No data, pesticide impairments present in watershed
- **Eliminated causes of fish IBI impairment:**
  - Altered interspecific competition: Stocking activities present
- **Recommendations:**
  - Follow TMDL and WRAPS recommendations and continue to promote and implement agricultural BMP's within the Redwood River Watershed to aid with reduction in nutrients, pesticides, and sediment coming from upstream and shoreland sources
  - Promote and maintain riparian areas with use of shoreline buffers
  - Promote growth of native aquatic vegetation
  - Natural lack of connectivity and unknown winterkill history could be influencing the fish community



For more information, contact IBI program watershed lead identified at: https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html

DEPARTMENT OF NATURAL RESOURCES

CLEAN WATER LAND & LEGACY AMENDMENT

Figure 11. Island Lake (42-0096-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

6. Conclusions and recommendations

Conclusions

Tables 9 and 10 present a summary of the stressors associated with the biologically impaired and vulnerable lakes in the CRW and RRW, respectively. Eutrophication (excess nutrients) is adversely affecting the fish communities in Double, Rock, Dead Coon, Benton, East Twin, Wood, and Island lakes. These lakes contain relatively high levels of nutrients such as total phosphorus (i.e., greater than 30–40 ppb) and are located in watersheds with high land use disturbance (i.e., greater than 40%).

Physical habitat alterations are an inconclusive stressor to the fish communities in Double, Rock, Dead Coon, Benton, East Twin, Wood and Island lakes. Aside from Lake Benton, residential shoreline development around these CRW and RRW lakes is low; however, agricultural land use within close proximity to the shorelines has resulted in some bank erosion and sedimentation concerns. High nutrient inputs and corresponding low water clarity have also contributed to low aquatic plant diversity. Additionally, several of these lakes (i.e., Double, Dead Coon, and Benton) are located in watersheds with connectivity concerns, such as culverts or crossings that potentially restrict fish passage. Conversely, several lakes (i.e., East Twin, Wood, and Island) are located in relatively isolated watersheds that lack significant inlets and outlets. This lack of connectivity could naturally be limiting species richness and ultimately have a negative influence on a lake's FIBI score.

Altered interspecific competition was determined to be an inconclusive stressor for all lakes that contained non-native species that have the potential to affect fish communities at high densities (e.g., Common Carp). Island Lake is currently the only lake where Common Carp have not been documented, and therefore altered interspecific competition was eliminated as a likely stressor. Many of the remaining lakes contained comparable densities of the non-native species in recent surveys when compared to similar lakes.

Decreased dissolved oxygen was determined to be an inconclusive stressor for all assessed lakes due to the uncertain effects of occasionally low observed winter dissolved concentrations and the presence of winter aeration systems in several lakes. Although significant winterkill events have not been documented recently in these lakes, there is still potential for conditions that may favor species that may be more tolerant of low dissolved oxygen levels. All assessed lakes are shallow and relatively small and therefore more likely to experience low winter dissolved oxygen concentrations naturally; however, excess nutrients may also exacerbate these conditions.

Pesticide application was also determined to be an inconclusive cause for all lakes, largely due to a lack of monitoring data and a lack of direct evidence that pesticides are a source of impairment. Results from National Lake Assessment monitoring in Minnesota indicate that the number of detected pesticides and total pesticide concentration in lakes is positively related to percent of watershed in cropland (MDA 2019), and a high proportion of each impaired or vulnerable lake's contributing watershed is cultivated. Although pesticide monitoring has not occurred within most CRW or RRW lakes, several pesticides, including acetochlor, chlorpyrifos, clothianidin, fomesafen, and imidacloprid were detected in several CRW and RRW lakes, streams, and rivers. In Double Lake, chlorpyrifos levels exceeded the chronic standard (>0.041 ppb), and as a result, Double Lake has been added to MPCA's impaired waters list for pesticides (MPCA 2020a).

Table 9. Summary of the stressors associated with the biologically impaired lakes in the Cottonwood River Watershed.

		Candidate causes[1]				
Lake name	DOW	Eutrophication (excess nutrients)	Physical habitat alteration	Altered interspecific competition	Decreased dissolved oxygen	Pesticide application
Double (North Portion)	17-0056-01	+	0	0	0	0
Rock	42-0052-00	+	0	0	0	0

[1] "+" supports the case for the candidate cause as a stressor, "-" refutes the case for the candidate cause as a stressor, and "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor.

Table 10. Summary of the stressors associated with the biologically impaired or vulnerable lakes in the Redwood River Watershed.

		Candidate causes[1]				
Lake Name	DOW	Eutrophication (excess nutrients)	Physical habitat alteration	Altered interspecific competition	Decreased dissolved oxygen	Pesticide application
Dead Coon	03-0107-00	+	0	0	0	0
Benton	03-0189-00	+	0	0	0	0
East Twin	03-0258-00	+	0	0	0	0
Wood	03-0286-00	+	0	0	0	0
Island	56-0385-00	+	0	-	0	0

[1] "+" supports the case for the candidate cause as a stressor, "-" refutes the case for the candidate cause as a stressor, and "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor.

Recommendations

The recommended actions listed below will help to reduce the influence or better understand the stressors that are limiting the fish communities found in lakes in the CRW and RRW. Collaboration among agencies, watershed districts, and local government units will be imperative for successful planning and implementation of these recommendations. Several examples of collaborative successes in other agricultural watersheds include a Dutch Creek habitat restoration project, which restored floodplain wetlands and upland habitat upstream of the Fairmont Chain of Lakes in the Blue Earth River Watershed, and a collaborative cover crop project to improve soil health and crop production while reducing fertilizer and sediment loads into Rice Creek, a trout stream in the Cannon River Watershed. These examples each involved numerous project, organizational, and funding partners that were critical to their success.

Eutrophication

Best management practices should be employed to reduce upstream inputs of nutrients into biologically impaired or vulnerable lakes. In agricultural areas, such practices may include applying correct fertilizer types at appropriate rates and times depending on soil type and other factors (e.g., weather), using no till or minimum tillage practices, planting cover crops, establishing and maintaining adequate riparian buffer zones around lakes, rivers, and ditches, using grass waterways and restored or constructed wetlands to filter nutrients from surface waters, and restoring marginal cropland back to native prairie

or wetland areas to increase water storage. Further, the use of cover crops on tiled land and land adjacent to lakes and streams in particular would contribute to reductions in nutrient, sediment, and chemical inputs entering surface waters. In residential areas located around biologically impaired lakes, practices may include minimizing application of lawn fertilizer, reestablishing or maintaining shoreline buffer zones, and ensuring individual sewage treatment systems remain compliant with state regulations (Minnesota Rules Chapter 7080) and local government ordinances. Where applicable, specific recommendations outlined in lake eutrophication TMDLs and WRAPS reports should also be followed to reduce potential nutrient inputs.

Acquisition of RIM conservation easements (BWSR 2021) may also be a viable option to protect lakes from eutrophication and other negative effects of development. Undeveloped or restored prairies or wetlands, such as those identified in Minnesota's restorable wetlands inventory (Ducks Unlimited 2014), can provide numerous benefits to the surrounding ecosystem including filtering surface runoff and thereby reducing eutrophication and sedimentation, recharging the groundwater supply, and removing carbon dioxide from the atmosphere.

When appropriate, in-lake treatment options, such as those outlined in the Minnesota state and regional government review of internal phosphorus load control report (MPCA 2020c), may also be carefully considered to reduce internal loading. These options would ideally come after external nutrient sources have largely been eliminated and watershed nutrient loads have been significantly reduced. Otherwise, any potential benefits from in-lake treatments options would be short-term at best.

Not only would the above actions likely improve fish community health as measured by the FIBI, they would also likely improve water clarity, improve habitat provided by more diverse and widely distributed aquatic plants, reduce the frequency and severity of low winter dissolved oxygen concentrations, and reduce pesticide concerns.

Physical habitat alteration

Although eutrophication has been identified as the primary cause of stress to the fish communities in CRW and RRW lakes, physical habitat alteration is occurring at various levels and could be addressed where appropriate, particularly when the actions would also result in nutrient reductions.

Low aquatic plant diversity in many CRW and RRW lakes is a direct result of eutrophication rather than physical removal by lakeshore owners. As such, aquatic plant communities present in CRW and RRW lakes would greatly benefit from nutrient reductions and improved water clarity, as opposed to other actions such as increased APM compliance checks that may be needed when shoreline development is a greater concern. As such, recommendations outlined to address eutrophication would also benefit the physical habitat that could be provided by aquatic plant communities in these lakes.

The shorelines of many of the CRW and RRW lakes contain a narrow band of trees and other plants; however, high agricultural land use within close proximity to some shorelines, and in some cases increasing water levels, has resulted in bank erosion concerns around several lakes (e.g., Double, Dead Coon, and East Twin lakes). Bank erosion can occur naturally due to water level fluctuations but can be exacerbated by other factors such as removal of riparian buffers. Bank erosion contributes sediment, as well as nutrients and other chemicals present on the land, directly into lakes, particularly during heavy rainfall events. Actions to identify, re-slope, and vegetate banks that are prone to erosion could be considered.

A majority of lakeshore parcels within the CRW and RRW are privately owned and have been either converted to agricultural land or, in fewer cases, residentially developed. However, in cases where shoreline and shoreland habitat has not been developed, land acquisition could still be considered as a viable protection option. Likewise, acquisition of RIM conservation easements and subsequent establishment of native vegetation can be considered to restore and protect wetlands, adjacent native grassland, and other riparian areas (BWSR 2021). Future acquisitions aimed at increasing the percentages of protected shoreline and protected watershed area could be given priority where feasible.

Recommendations related to other physical habitat alteration concerns should also be considered where appropriate. Upstream and downstream connections should be restored when crossings (i.e., water control structures, culverts, and crossings) have been identified as barriers to native fish passage and risks associated with potential upstream movement of non-native species (e.g., Bighead and Silver Carp) via the Minnesota River have been considered. Additionally, unevaluated crossings should be inspected for potential concerns. Non-native species (e.g., Common Carp and Curly-leaf Pondweed) should continue to be monitored in lakes where they are present to ensure they do not exceed densities that substantially alter physical habitat. If densities are determined to be high enough to be detrimental to physical habitat, removal options could be considered. Finally, efforts to reduce the spread of non-native species, including those that are absent from the CRW and RRW (e.g., Eurasian Watermilfoil, Zebra Mussels, and Bighead and Silver Carp), should continue to be encouraged.

Altered interspecific competition

Altered interspecific competition was not identified as a candidate cause of stress in any biologically impaired or vulnerable lakes. Nonetheless, monitoring efforts to better understand densities and potential effects of species such as Common Carp should be considered. Monitoring of stocking and harvest-related activities should also continue as these data can help inform future changes within biologically impaired or vulnerable lakes.

Efforts to reduce densities of Common Carp within CRW and RRW lakes via seining have occurred historically but were largely unsuccessful at that time. Present day commercial harvest, although typically targeting Bigmouth Buffalo, also occurs occasionally in some lakes; however, there is not a concerted effort to remove Common Carp or reduce densities of the species. Common Carp typically occur at moderate to high densities in these lakes and therefore modern density control methods may provide viable options to consider under the appropriate circumstances. However, efforts may be expensive, may have varying success, and may also block migrations of native species.

Decreased dissolved oxygen

Since eutrophication may exacerbate low winter oxygen concentrations in small, shallow lakes, actions intended to reduce nutrient inputs, as are outlined in the eutrophication recommendations, may reduce the frequency and severity of such events.

Pesticide application

Agricultural land use is prevalent within the CRW and RRW, which results in a high potential for varying types and concentrations of pesticides to enter surface waters. Monitoring, and funding for monitoring, is needed to evaluate the extent of pesticide use within each lake's contributing watershed, the number

of pesticides and total concentration present in each lake, and any potential negative effects to the fish community that may be occurring as a result. Neonicotinoid monitoring, in particular, should become a standard practice on more lakes due to its water solubility, prevalence, and potential impacts to aquatic organisms.

References

Atwood, D., and C. Paisley-Jones. 2017. Pesticides industry sales and usage: 2008–2012 market estimates. USEPA, Washington, D.C.

Bacigalupi, J., D. F. Staples, M. T. Treml, and D. L. Bahr. 2021. Development of fish-based indices of biological integrity for Minnesota lakes. Ecological Indicators 125:107512.

BWSR (Minnesota Board of Water and Soil Resources). 2021. Reinvest in Minnesota overview. BWSR, St. Paul, Minnesota. Available: http://bwsr.state.mn.us/reinvest-minnesota-overview. (February 2021).

Corbin, M., and C. Flaherty. 2009. Problem formulation for the environmental fate and ecological risk, endangered species and drinking water assessments in support of the registered review of chlorpyrifos. USEPA, Washington, D.C.

Cormier, S., S. Norton, G. Suter, and D. Reed-Judkins. 2000. Stressor identification guidance document. U.S. Environmental Protection Agency, Washington D.C., EPA/822/B-00/025. Available: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=20685. (March 2019).

Cross, T. K., and P. C. Jacobson. 2013. Landscape factors influencing lake phosphorus concentrations across Minnesota. Lake and Reservoir Management 29:1–12.

Douglas, M. R., and J. F. Tooker. 2015. Large-scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in US field crops. Environmental Science and Technology 49:5088–5097.

Drake, M. T., and D. L. Pereira. 2002. Development of a fish-based index of biotic integrity for small inland lakes in central Minnesota. North American Journal of Fisheries Management 22:1105–1123.

Ducks Unlimited. 2014. Minnesota restorable wetlands. Ducks Unlimited, Bismark, North Dakota. Available: https://www.ducks.org/conservation/geographic-information-systems/minnesota-restorable-wetlands (February 2021).

Dustin, D. L., and B. Vondracek. 2017. Nearshore habitat and fish assemblages along a gradient of shoreline development. North American Journal of Fisheries Management 37:432–444.

Goulson, D. 2014. Pesticides linked to bird declines. Nature 511:295–296.

Greenbank, J. 1945. Limnological conditions in ice-covered lakes, especially as related to winter-kill of fish. Ecological Monographs 14:343–392.

Jacobson, P. C., T. K. Cross, D. L. Dustin, and M. Duval. 2016. A fish habitat conservation framework for Minnesota lakes. Fisheries 41:302–317.

Köhler, H. R., and R. Triebskorn. 2013. Wildlife ecotoxicology of pesticides: can we track effects to the population level and beyond? Science 341:759–765.

Krupke, C. H. and J. F. Tooker. 2020. Beyond the headlines: the influence of insurance pest management on an unseen, silent entomological majority. Frontiers in Sustainable Food Systems 4:595855.

Mathias, J. A., and J. Barica. 1980. Factors controlling oxygen depletion in ice-covered lakes. Canadian Journal of Fisheries and Aquatic Science 37:185–194.

MDA (Minnesota Department of Agriculture). 2018. 2018 water quality monitoring report. MDA, St. Paul, MN.

MDA. 2019. Pesticides in Minnesota lakes. MDA, St. Paul, Minnesota. Available: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3462/datastream/PDF/view. (December 2020).

MDA. 2020. Pesticide sales database. MDA, St. Paul, Minnesota. Available: https://www.mda.state.mn.us/minnesota-pesticide-sales-information. (December 2020).

Meding, M. E., and L. J. Jackson. 2003. Biotic, chemical, and morphometric factors contributing to winter anoxia in prairie lakes. Limnological Oceanography 48:1633–1962.

MNDNR (Minnesota Department of Natural Resources). 2018a. Stressors to biological communities in Minnesota's lakes. MNDNR, Brainerd, Minnesota. Available: https://files.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/bio-communities-stressors.pdf. (December 2020).

MNDNR. 2018b. Watershed health assessment framework. MNDNR, St. Paul, Minnesota. Available: http://www.dnr.state.mn.us/whaf/index.html. (November 2018).

MNDNR. 2018c. Fishes of Minnesota mapper. MNDNR, St. Paul, Minnesota. Available: https://www.dnr.state.mn.us/maps/fom/mapper.html. (November 2018).

MNDNR. 2018d. Lake Benton, Lincoln County aquatic vegetation report. MNDNR, St. Paul, Minnesota.

MNDNR. 2020a. Cottonwood River Watershed characterization report. MNDNR, St. Paul, Minnesota. Available: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3615. (February 2021).

MNDNR. 2020b. Redwood River Watershed characterization report. MNDNR, St. Paul, Minnesota. Available: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3670. (February 2021).

MNDNR. 2020c. Minnesota climate trends. MNDNR, St. Paul, Minnesota. Available: https://arcgis.dnr.state.mn.us/ewr/climatetrends/. (December 2020)

MPCA (Minnesota Pollution Control Agency). 2007. Minnesota statewide mercury total maximum daily load. MPCA, St. Paul, Minnesota.

MPCA. 2020a. Minnesota's impaired waters list. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list. (December 2020).

MPCA. 2020b. Shapefile: what's in my neighborhood (WIMN). MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/document/env-my-neighborhood. (December 2020).

MPCA. 2020c. Minnesota state and regional government review of internal phosphorus load control. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/sites/default/files/wq-s1-98.pdf. (December 2020)

MPCA. 2021a. Cottonwood River Watershed Stressor Identification Report—Streams. MPCA, St. Paul, Minnesota.

MPCA. 2021b. Redwood River Watershed Stressor Identification Report—Streams. MPCA, St. Paul, Minnesota.

MPCA. 2021c. Shapefile: feedlots in Minnesota. MPCA, St. Paul, Minnesota. Available: https://gisdata.mn.gov/dataset/env-feedlots. (April 2021).

MPCA. 2021d. Cottonwood River Watershed Total Maximum Daily Load. MPCA, St. Paul, Minnesota.

MPCA. 2021e. Cottonwood River Watershed Restoration and Protection Strategies. MPCA, St. Paul, Minnesota.

MPCA. 2021f. Redwood River Watershed Total Maximum Daily Load. MPCA, St. Paul, Minnesota.

MPCA. 2021g. Redwood River Watershed Restoration and Protection Strategies. MPCA, St. Paul, Minnesota.

Minnesota Rules Chapter 7050. Standards for the Protection of the Quality and Purity of the Waters of the State. Revisor of Statutes and Minnesota Pollution Control Agency, St. Paul, Minnesota. Available: https://www.revisor.mn.gov/rules/7050/ (November 2019).

Minnesota Rules Chapter 7080. Individual Subsurface Sewage Treatment Systems. Revisor of Statutes and Minnesota Pollution Control Agency, St. Paul, Minnesota. Available: https://www.revisor.mn.gov/rules/7080/ (November 2019).

Morrissey, C. A., P. Mineau, J. H. Devries, F. Sanchez-Bayoe, M. Liess, M. C. Cavallaro, and K. Liber. 2015. Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: a review. Environment International, 74:291–303.

Perleberg, D., P. Radomski, S. Simon, K. Carlson, C. Millaway, J. Knopik, and B. Holbrook. 2019. Minnesota lake plant survey manual, version 3, for use by Fisheries Section, EWR Lake Unit, and EWR Minnesota Biological Survey Unit. MNDNR, Ecological and Water Resources Division, Brainerd, Minnesota.

Robertson, D. M., and R. A. Ragotzkie. 1990. Changes in the thermal structure of moderate to large sized lakes in response to changes in air temperature. Aquatic Sciences 54:360–380.

Schultz, B, and T. Sledge. 1997. Lakes Benton and Hendricks creel surveys, summer of 1996 and winter of 1996-97. MNDNR Completion Report Job 412A, Windom, Minnesota.

Yamamuro, M., T. Komuro, H. Kamiya, T. Kato, H. Hasegawa, and Y. Kameda. 2019. Neonicotinoids disrupt aquatic food webs and decrease fishery yields. Science 366:620–623.

USDA (United States Department of Agriculture). 2017. Quick stats. USDA, Washington, D.C. Available: https://www.quickstats.nass.usda.gov/. (December 2020).

Valley, R. D., T. K. Cross, and P. Radomski. 2004. The role of submersed aquatic vegetation as habitat for fish in Minnesota lakes, including the implications of non-native plant invasions and their management. MNDNR Special Publication 160, St. Paul, MN.