Stressor identification – Lakes

March 2020

Otter Tail River Watershed Stressor Identification Report—Lakes

A study of local stressors limiting the biotic communities in lakes within the Otter Tail River Watershed.

DEPARTMENT OF NATURAL RESOURCES

MINNESOTA POLLUTION CONTROL AGENCY

WILDLIFE & SPORT FISH RESTORATION

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover photo-Healthy emergent and floating-leaf plant community in North Lida Lake.

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Key terms and abbreviations

APM	Aquatic Plant Management
AMA	Aquatic Management Area
Contributing watershed	All upstream areas bounded peripherally by a divide that ultimately drain into a particular watercourse or water body
DO	Dissolved oxygen
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
EPA	United States Environmental Protection Agency
FIBI	Fish-based lake index of biological integrity; an index developed by the MNDNR 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
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
OTRW	Otter Tail River Watershed
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
Vegetative 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

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 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 Otter Tail River Watershed (OTRW). The OTRW encompasses over 1.2 million acres characterized predominantly as a mix of forested and agricultural land, and includes the cities of Detroit Lakes, Fergus Falls, Pelican Rapids, and Perham. The OTRW also contains numerous lakes, rivers, streams, and wetland complexes.

Of the lakes within the OTRW, 86 were sampled and assessed using the FIBI to evaluate biological health. Of the lakes that were sampled, 12 were assessed as not supporting aquatic life use based on FIBI scores that were below the impairment threshold established for similar lakes. Seven additional lakes were considered vulnerable to future impairment based on FIBI scores near the impairment threshold.

After examining many candidate causes for the biological impairments, the following stressors were identified as probable causes of stress to aquatic life within the OTRW:

- Eutrophication
- Physical habitat alteration
- Temperature regime changes
- Decreased dissolved oxygen

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 OTRW, water quality standards, and general effects on biology. Sections 4 and 5 are organized by impaired or vulnerable lake 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 (Table 1; Table 3). More information on the 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 insectivore species captured in all gear	X			X
Number of omnivore 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 vegetative dwelling species captured in all gear	X	X		X
Community composition metrics				
Relative abundance of intolerant species in nearshore sampling	X		X	

	FIBI tool			
Lake characteristics	**2**	**4**	**5**	**7**
Relative abundance of small benthic dwelling species in nearshore sampling	X	X		
Relative abundance of vegetative dwelling species in nearshore sampling				X
Proportion of biomass in trap nets from insectivore species	X	X	X	X
Proportion of biomass in trap nets from omnivore 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.

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 (EPA) 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.

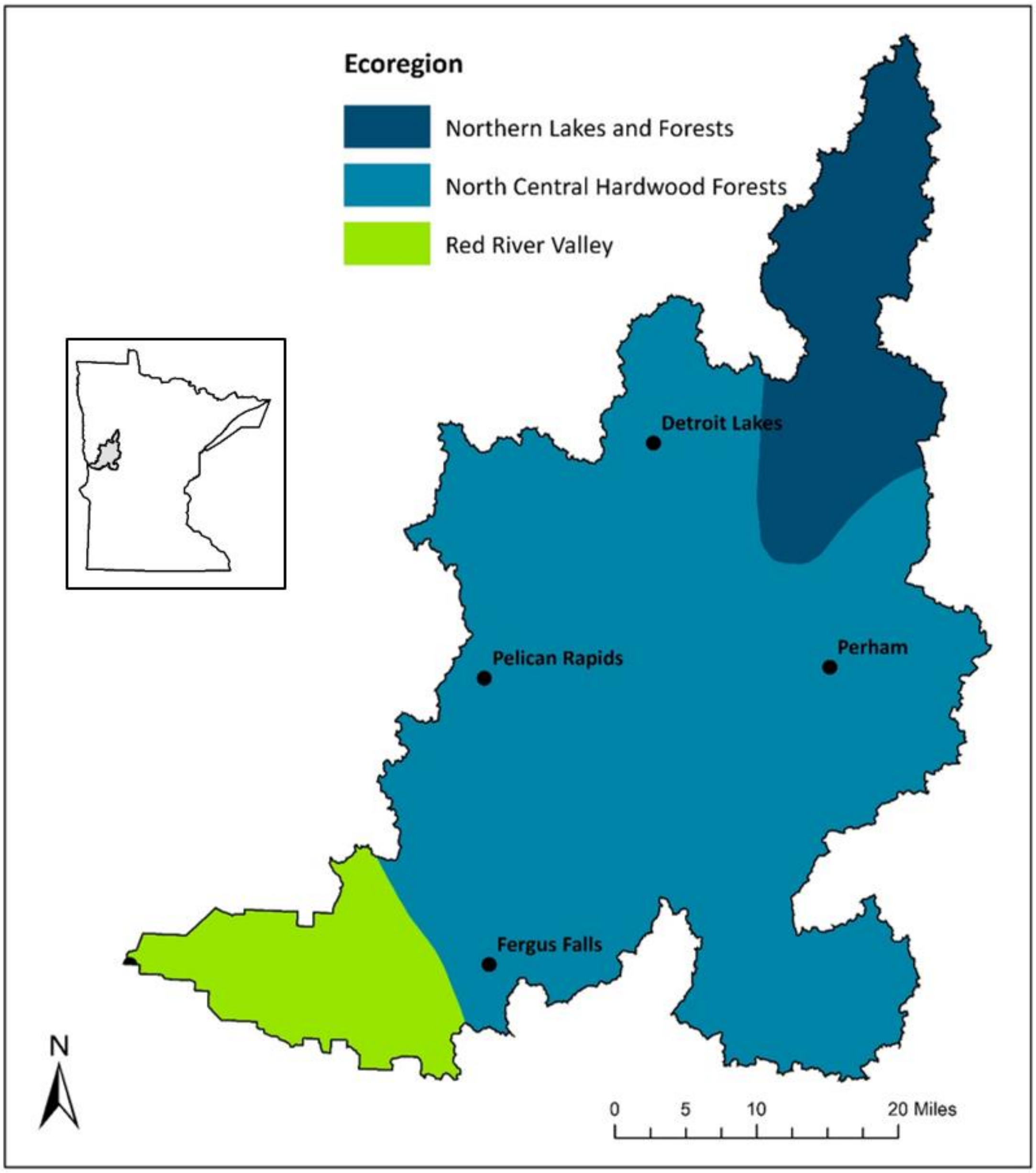
Stressor	Examples of anthropogenic sources	Examples of links to aquatic biology
Eutrophication	Inputs of excessive nutrients from agricultural runoff, animal waste, fertilizer, industrial and municipal wastewater facility discharges, non-compliant septic system effluents, and urban stormwater runoff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

2.1. Background

The Otter Tail River Watershed (OTRW) encompasses over 1.2 million acres characterized predominantly as a mix of forested and agricultural land, and includes the cities of Detroit Lakes, Fergus Falls, Pelican Rapids, and Perham (Figure 1). The OTRW also contains numerous lakes, rivers, streams, and wetland complexes. From northeast to southwest, the OTRW is contained within three ecoregions: Northern Lakes and Forests, North Central Hardwood Forest, and Red River Valley.

Figure 1. Location of the Otter Tail River Watershed in Minnesota.



2.2. Monitoring and summary of biological impairments

The FIBI was used to assess 86 lakes in the OTRW (Figure 2; Table 4). A total of 65 lakes had FIBI scores at or above the impairment threshold and were assessed as fully supporting aquatic life use (Table 3; Table 4). Nine lakes were deemed to have insufficient information to make an assessment decision (Table 4). Lakes considered to have insufficient information to make an assessment decision either lacked sufficient sampling effort or recent survey data, or lake characteristics did not facilitate use of one of the four FIBI tools. Seven lakes assessed as either fully supporting or insufficient information were considered to be vulnerable to future impairment. These lakes include Toad (03-0107-00), Little Toad (03-0189-00), Acorn (03-0258-00), Cotton (03-0286-00), Sallie (03-0359-00), Big Cormorant (03-0576-00), and Star (03-0385-00). Twelve lakes were assessed as not supporting aquatic life use because they had FIBI scores that were below the impairment threshold (Table 4). These lakes include Eagle (03-0265-00), Little Cormorant (03-0506-00), Upper Cormorant (03-0588-00), Middle Cormorant (03-0602-00), Walker (56-0310-00), Little McDonald (56-0328-00), Paul (56-0335-00), Big McDonald (56-0386-01), Anna (56-0448-00), West Silent (56-0519-00), Fish (56-0684-00), and Jewett (56-0877-00). The remainder of this document will review stressor information for the OTRW lakes that were either assessed as not supporting aquatic life use or considered vulnerable to future impairment.

Table 3. Lake FIBI tools with respective number of lakes assessed in the OTRW, FIBI thresholds, and lower/upper 90% confidence limits (CL).

Lake FIBI tool	Number of OTRW lakes assessed	FIBI threshold	Lower CL	Upper CL
Tool 2	52	45	36	54
Tool 4	20	38	30	46
Tool 5	7	24	9	39
Tool 7	5	36	27	45

Figure 2. OTRW land cover classes 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 considered vulnerable to future impairment.

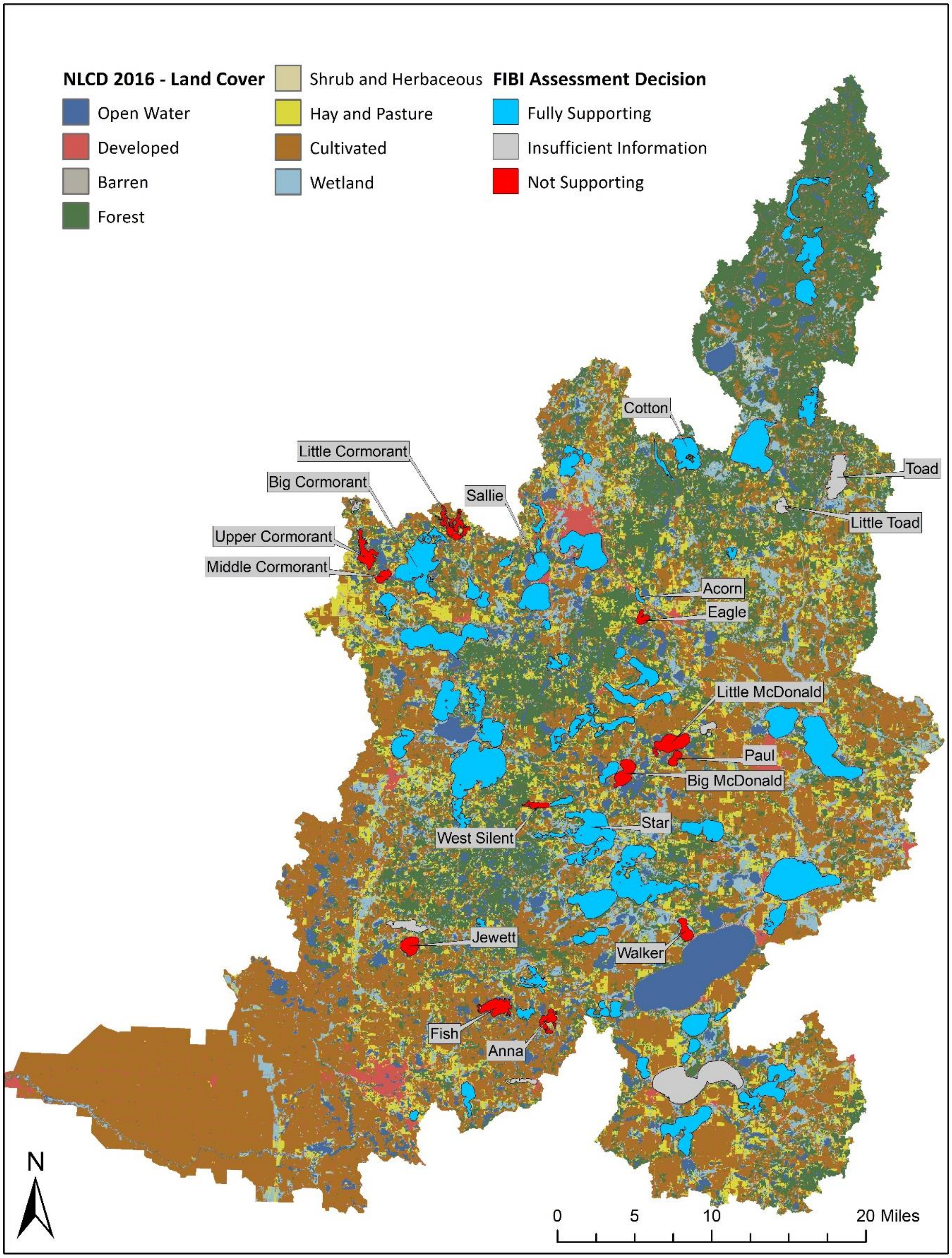


Table 4. Summary of lakes in the OTRW assessed with FIBI tools.

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% littoral[1]	FIBI score(	Below impairment threshold	Assessment status[2]
03-0107-00	Toad	Becker	2016, 2017		1,716	2	33	45, 42	No, Yes	IF-Vuln
03-0136-00	Juggler	Becker	2017		428	2	35	50	No	FS
03-0153-00	Island	Becker	7/2016, 8/2016		1,179	2	41	44, 52	Yes, No	FS
03-0155-00	Round	Becker	2015		1,094	2	43	77	No	FS
03-0158-00	Many Point	Becker	2013	Low sampling effort	1,701	2	29	57	No	FS
03-0159-00	Elbow	Becker	2012, 2015	Low sampling effort (2012)	985	2	25	57, 81	No, No	FS
03-0166-00	Hungry	Becker	2013, 2016	Difficult sampling conditions, Low sampling effort (2013)	241	4	76	35, 41	Yes, No	FS
03-0189-00	Little Toad	Becker	2013, 2016	Low sampling effort (2013)	405	2	34	28, 46	Yes, No	IF-Vuln
03-0195-00	Height of Land	Becker	2015		3,790	7	91	69	No, No	FS
03-0234-00	Little Bemidji	Becker	2013	Low sampling effort	293	2	24	62	No	FS
03-0258-00	Acorn	Becker	2013, 2016	Low sampling effort (2013)	154	4	48	32, 39	Yes, No	FS-Vuln
03-0265-00	Eagle	Becker	2017		320	4	44	33	Yes	NS
03-0286-00	Cotton	Becker	2016		1,783	2	44	46	No	FS-Vuln
03-0287-00	Pickerel	Becker	2011, 2017	Low sampling effort (2011)	361	2	34	54, 54	No, No	FS
03-0355-00	Sauer	Becker	2015		180	4	41	54	No	FS
03-0357-00	Munson	Becker	2015		134	4	49	51	No	FS
03-0359-00	Sallie	Becker	2016		1,273	2	45	44, 51	Yes, No	FS-Vuln
03-0381-00	Detroit	Becker	2007, 2011, 2015	Sampling completed outside of 10-year assessment window (2007)	3,067	2	61	46, 53, 63	No, No, No	FS
03-0383-00	Long	Becker	2011, 2016		409	2	44	62, 72	No, No	FS
03-0386-00	Little Floyd	Becker	2011, 7/12/2016, 7/14/2016		214	4	55	63, 48, 47	No, No, No	FS
03-0387-00	Floyd	Becker	2016		1,178	2	69	54	No	FS

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% littoral[1]	FIBI score(	Below impairment threshold	Assessment status[2]
03-0475-00	Melissa	Becker	2014		1,850	2	49	66	No	FS
03-0486-00	Pearl	Becker	2014	Low sampling effort	280	5	71	62	No	FS
03-0500-00	Maud	Becker	7/2010, 8/2010, 2014		517	4	51	55, 66, 50	No, No, No	FS
03-0503-00	Eunice	Becker	2010, 2014, 2017		378	4	49	31, 54, 56	Yes, No, No	FS
03-0506-00	Little Cormorant	Becker	2012, 2016	Low sampling effort (2012)	1,067	2	72	14, 26	Yes, Yes	NS
03-0575-00	Leif	Becker	2013		521	5	71	51	No	FS
03-0576-00	Big Cormorant	Becker	2014, 2015		3,657	2	23	41, 46	Yes, No	FS-Vuln
03-0582-00	Ida	Becker	2013		630	5	77	49	No	FS
03-0588-00	Upper Cormorant	Becker	2008, 8/6/2012, 8/7/2012, 2017	Low sampling effort (2008), Sampling completed outside of 10-year assessment window (2008)	927	2	51	32, 42, 35, 27	Yes, Yes, Yes, Yes	NS
03-0602-00	Middle Cormorant	Becker	2010, 2014		366	4	71	29, 35	Yes, Yes	NS
03-0638-00	Bijou	Becker	6/2011, 8/2011, 2017		210	5	57	4, 9, 31	Yes, Yes, No	IF
15-0108-00	Pickerel	Clearwater	2014		143	4	37	62	No	FS
56-0130-00	Big Pine	Otter Tail	2017		4,726	2	50	49	No	FS
56-0138-00	East Battle	Otter Tail	2017		1,985	2	42	53	No	FS
56-0141-00	Rush	Otter Tail	7/2016, 8/2016		5,234	2	63	47, 58	No, No	FS
56-0142-00	Little Pine	Otter Tail	2017		2,080	2	34	63	No	FS
56-0191-00	Stuart	Otter Tail	2015		747	2	54	59	No	FS
56-0193-00	Ethel	Otter Tail	2014, 2017		190	2	36	39, 55	Yes, No	FS
56-0209-00	Buchanan	Otter Tail	2014		963	7	87	64	No	FS
56-0238-00	Clitherall	Otter Tail	2012		2,540	2	33	56	No	FS

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% littoral[1]	FIBI score(	Below impairment threshold	Assessment status[2]
56-0239-00	West Battle	Otter Tail	2007	Sampling completed outside of 10-year assessment window	5,565	2	46	49	No	IF
56-0240-00	Blanche	Otter Tail	2015		1,296	2	80	55	No	FS
56-0241-00	Annie Battle	Otter Tail	2010, 2014		354	4	57	60, 58	No, No	FS
56-0243-00	Marion	Otter Tail	2012		1,624	2	41	54	No	FS
56-0245-00	Devils	Otter Tail	2007	Sampling completed outside of 10-year assessment window	355	2	59	48	No	IF
56-0298-00	Deer	Otter Tail	2014		447	4	67	58	No	FS
56-0302-01	First Silver	Otter Tail	2016		528	4	44	50	No	FS
56-0303-00	Molly Stark	Otter Tail	7/2010, 8/2010, 7/6/2015, 7/30/2015		152	4	41	75, 83, 84, 82	No, No, No, No	FS
56-0310-00	Walker	Otter Tail	2013		578	4	62	31	Yes	NS
56-0328-00	Little McDonald	Otter Tail	2016, 2017		1,312	2	31	41, 42	Yes, Yes	NS
56-0335-00	Paul	Otter Tail	2015		347	2	31	32	Yes	NS
56-0358-00	Scalp	Otter Tail	2013		254	2	27	74	No	FS
56-0360-00	Rose	Otter Tail	2013		1,200	2	41	70	No	FS
56-0378-00	East Lost	Otter Tail	2014, 2017		483	4	68	36, 53	Yes, No	FS
56-0383-00	Dead	Otter Tail	2017		7,535	7	87	45	No	FS
56-0385-00	Star	Otter Tail	2008, 2017	Sampling completed outside of 10-year assessment window (2008)	4,454	2	63	58, 45	No, No	FS-Vuln
56-0386-01	Big McDonald	Otter Tail	2013		992	2	37	30	Yes	NS
56-0386-02	West McDonald	Otter Tail	2007, 2015	Sampling completed outside of 10-year assessment window (2007)	597	2	31	58, 46	No, No	FS

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% littoral[1]	FIBI score(	Below impairment threshold	Assessment status[2]
56-0387-00	Sybil	Otter Tail	2013		682	2	41	47	No	FS
56-0388-02	Long (main lake)	Otter Tail	2007, 7/2015, 8/2015	Sampling completed outside of 10-year assessment window (2007), Low sampling effort (7/2015)	1,289	2	41	60, 50, 66	No, No, No	FS
56-0448-00	Anna	Otter Tail	2009, 2014	Low sampling effort (2009)	598	4	62	12, 15	Yes, Yes	NS
56-0449-00	Pleasant	Otter Tail	2013		385	4	61	51	No	FS
56-0475-00	Pickerel	Otter Tail	2016		849	2	29	57	No	FS
56-0476-00	Maine (Round)	Otter Tail	2007	Sampling completed outside of 10-year assessment window (2007), Smaller than 100 acres	88	4	40	47	No	IF
56-0481-00	West Lost	Otter Tail	2017		757	5	91	34	No	FS
56-0501-00	East Spirit	Otter Tail	2013		561	2	44	52	No	FS
56-0517-00	East Silent	Otter Tail	2013		324	2	18	58	No	FS
56-0519-00	West Silent	Otter Tail	2010, 2014, 2017		347	2	34	59, 43, 39	No, Yes, Yes	NS
56-0523-00	East Loon	Otter Tail	2008, 2013, 2016	Sampling completed outside of 10-year assessment window (2008)	1,044	2	57	34, 52, 57	Yes, No, No	FS
56-0532-00	Leek	Otter Tail	2014		621	2	49	56	No	FS
56-0570-00	Bass	Otter Tail	2014	Uncertainty regarding Schupp Lake Class assignment and FIBI tool	308	5	45	39	No	IF
56-0658-00	Wall	Otter Tail	2013		728	4	31	54	No	FS
56-0684-00	Fish	Otter Tail	2007, 2015, 2017	Schupp Lake Class 40 not represented in FIBI tool development, Sampling completed outside of 10-year assessment window (2007)	1,078	7	82	35, 32, 31	Yes, Yes, Yes	NS
56-0695-00	Heilberger	Otter Tail	2014		221	5	44	49	No	FS

DOW	Lake name	County	Nearshore survey year(s)	Notes	DNR GIS acres	FIBI tool	% littoral[1]	FIBI score(	Below impairment threshold	Assessment status[2]
56-0724-00	Beers	Otter Tail	1997	Sampling completed outside of 10-year assessment window (1997)	317	2	30	54	No	IF
56-0747-01	North Lida	Otter Tail	2017		5,514	2	43	57	No	FS
56-0747-02	South Lida	Otter Tail	2015		775	2	41	58	No	FS
56-0749-00	Crystal	Otter Tail	2014		1,412	2	50	67	No	FS
56-0759-00	Franklin	Otter Tail	2016		1,088	2	49	56	No	FS
56-0760-01	Lizzie (north portion)	Otter Tail	2007, 2016	Sampling completed outside of 10-year assessment window (2007)	1,900	2	43	44, 59	Yes, No	FS
56-0784-00	Long	Otter Tail	2007	Sampling completed outside of 10-year assessment window	767	2	38	47	No	IF
56-0786-00	Pelican	Otter Tail	2008, 2015	Sampling completed outside of 10-year assessment window (2008)	3,963	2	41	47, 61	No, No	FS
56-0829-00	Pebble	Otter Tail	2007, 2017	Sampling completed outside of 10-year assessment window (2007)	195	4	34	47, 61	No, No	FS
56-0877-00	Jewett	Otter Tail	2011, 2014	Difficult sampling conditions	731	2	36	43, 43	Yes, Yes	NS
56-0915-00	Prairie	Otter Tail	8/2013, 9/2013		1,003	7	79	94, 99	No, No	FS
≤ 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] "FS" indicates fully supporting aquatic life use, "IF" indicates insufficient information, "NS" indicates not supporting aquatic life use, and "Vuln" indicates vulnerable to future impairment.

Table 5. Comparison of common fish species (occurring in 50% or more of lakes) captured[1] in OTRW lakes assessed as fully supporting aquatic life use (marked with an "X" in the tool 2 column) relative to species captured in respective impaired lakes that were scored with fish index of biological integrity (FIBI) tool 2.

Species	Tolerance, feeding, and/or habitat guild[2]	FIBI tool 2	Little Cormorant 03-0506-00	Upper Cormorant 03-0588-00	Little McDonald 56-0328-00	Paul 56-0335-00	Big McDonald 56-0386-01	West Silent 56-0519-00	Jewett 56-0877-00
Banded Killifish	Nat, Int, Ins, Veg	X		NS	NS	NS	NS	NS	NS
Bigmouth Shiner	Nat, Ins, Cyp				NS		NS		
Black Bullhead	Nat, Tol, Omn	X	NS, GN, TN	NS		NS		TN	
Black Crappie	Nat, TC	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	GN, TN	GN, TN	NS, GN, TN	NS, GN, TN
Blackchin Shiner	Nat, Int, Ins, Veg, Cyp	X		NS	NS		NS	NS	
Blacknose Shiner	Nat, Int, Ins, Veg, Cyp	X		NS	NS			NS	NS
Bluegill	Nat, Ins	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Bluntnose Minnow	Nat, Omn, Cyp	X		NS	NS	NS	NS	NS	NS
Bowfin	Nat, TC, Veg	X							
Brook Stickleback	Nat, Ins								
Brown Bullhead	Nat, Omn	X	GN, TN	NS, GN, TN	GN	GN, TN	GN, TN	GN	GN, TN
Central Mudminnow	Nat, Ins, Veg		NS	NS	NS			NS	
Channel Catfish	Nat, TC								GN
Cisco	Nat, Int, Ins	X							GN
Common Carp	Tol, Omn			NS, GN, TN					
Common Shiner	Nat, Ins, Cyp								
Fathead Minnow	Nat, Tol, Omn, Cyp	X		NS					NS
Golden Shiner	Nat, Ins, Cyp	X	NS	NS				NS	NS
Green Sunfish	Nat, Tol, Ins	X	NS, TN	NS, TN			NS		NS

Species	Tolerance, feeding, and/or habitat guild[2]	FIBI tool 2	Little Cormorant 03-0506-00	Upper Cormorant 03-0588-00	Little McDonald 56-0328-00	Paul 56-0335-00	Big McDonald 56-0386-01	West Silent 56-0519-00	Jewett 56-0877-00
Hornyhead Chub	Nat, Ins, Cyp				NS				
Iowa Darter	Nat, Int, Ins, Smb, Veg	X		NS	NS			NS	NS
Johnny Darter	Nat, Ins, Smb	X		NS	NS	NS	NS	NS	NS
Largemouth Bass	Nat, TC	X	NS, GN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Least Darter	Nat, Int, Ins, Smb, Veg								
Logperch	Nat, Int, Ins, Smb	X		NS					
Mimic Shiner	Nat, Int, Ins, Veg, Cyp	X			NS	NS	NS		
Mottled Sculpin	Nat, Int, Ins, Smb								
Northern Pike	Nat, TC, Veg	X	GN, TN	NS, GN, TN	NS, GN	GN, TN	GN, TN	NS, GN, TN	GN, TN
Northern Redbelly Dace	Nat, Veg, Cyp								
Pugnose Shiner	Nat, Int, Ins, Veg, Cyp			NS					
Pumpkinseed	Nat, Ins	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Rock Bass	Nat, Int, TC	X	GN		NS, GN, TN		GN, TN	NS, TN	TN
Smallmouth Bass	Nat, Int, TC								
Spottail Shiner	Nat, Ins, Cyp	X	NS	NS	NS		NS	NS	NS
Tadpole Madtom	Nat, Ins, Smb, Veg	X		NS					
Walleye	Nat, TC	X	GN, TN	GN, TN	GN, TN	GN, TN	GN, TN	GN, TN	NS, GN, TN
Weed Shiner	Nat, Veg, Cyp			NS					
Western Blacknose Dace	Nat, Ins, Smb, Cyp								NS
White Sucker	Nat, Omn	X	GN	GN, TN	NS, GN, TN	GN, TN		GN	NS, GN, TN
Yellow Bullhead	Nat, Omn	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]	FIBI tool 2	Little Cormorant 03-0506-00	Upper Cormorant 03-0588-00	Little McDonald 56-0328-00	Paul 56-0335-00	Big McDonald 56-0386-01	West Silent 56-0519-00	Jewett 56-0877-00
Yellow Perch	Nat, Ins	X	NS, GN, TN	NS, GN, TN	NS, GN	NS, GN	NS, GN, TN	NS, GN, TN	NS, GN, TN

[1] Sampling methods that the species were captured with are abbreviated as follows: NS=Backpack Electrofishing and Seining, GN=Gillnetting, and TN=Trap Netting.

[2] Tolerance, feeding, and habitat guilds are abbreviated as follows: Nat=Native, Int=Intolerant, Tol=Tolerant, Ins=Insectivore, Omn=Omnivore, TC=Top Carnivore, Smb=Small Benthic Dweller, Veg=Vegetative Dweller, and Cyp=Cyprinid. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

Table 6. Comparison of common fish species (occurring in 50% or more of lakes) captured[1] in OTRW lakes assessed as fully supporting aquatic life use (marked with an "X" in the tool 2 column) relative to species captured in respective vulnerable lakes that were scored with fish index of biological integrity (FIBI) tool 2.

Species	Tolerance, feeding, and/or habitat guild[2]	FIBI tool 2	Toad 03-0107-00	Little Toad 03-0189-00	Cotton 03-0286-00	Sallie 03-0359-00	Big Cormorant 03-0576-00	Star 56-0385-00
Banded Killifish	Nat, Int, Ins, Veg	X	NS	NS	NS	NS	NS	NS
Bigmouth Shiner	Nat, Ins, Cyp							
Black Bullhead	Nat, Tol, Omn	X	NS, GN		NS	NS, GN, TN	GN	NS, GN
Black Crappie	Nat, TC	X	NS, GN, TN	NS, GN	GN, TN	GN, TN	GN, TN	NS, GN, TN
Blackchin Shiner	Nat, Int, Ins, Veg, Cyp	X	NS	NS		NS	NS	NS
Blacknose Shiner	Nat, Int, Ins, Veg, Cyp	X	NS	NS	NS	NS	NS	NS
Bluegill	Nat, Ins	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Bluntnose Minnow	Nat, Omn, Cyp	X	NS	NS	NS	NS	NS	NS
Bowfin	Nat, TC, Veg	X	NS, GN, TN	TN		TN		NS, GN, TN
Brook Stickleback	Nat, Ins		NS	NS		NS	NS	NS
Brown Bullhead	Nat, Omn	X	GN, TN	TN	GN, TN	GN, TN	NS, GN	NS, GN, TN
Central Mudminnow	Nat, Ins, Veg		NS			NS		NS
Channel Catfish	Nat, TC							
Cisco	Nat, Int, Ins	X			GN	GN		
Common Carp	Tol, Omn		TN	TN			TN	NS, TN
Common Shiner	Nat, Ins, Cyp		NS					
Fathead Minnow	Nat, Tol, Omn, Cyp	X		NS	NS	NS		NS
Golden Shiner	Nat, Ins, Cyp	X	NS	NS		NS		NS
Green Sunfish	Nat, Tol, Ins	X			NS	NS	NS	NS
Hornyhead Chub	Nat, Ins, Cyp						NS	
Iowa Darter	Nat, Int, Ins, Smb, Veg	X	NS	NS	NS	NS	NS	NS

Species	Tolerance, feeding, and/or habitat guild[2]	FIBI tool 2	Toad 03-0107-00	Little Toad 03-0189-00	Cotton 03-0286-00	Sallie 03-0359-00	Big Cormorant 03-0576-00	Star 56-0385-00
Johnny Darter	Nat, Ins, Smb	X	NS	NS	NS	NS	NS	NS
Largemouth Bass	Nat, TC	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Least Darter	Nat, Int, Ins, Smb, Veg		NS	NS				
Logperch	Nat, Int, Ins, Smb	X			NS	NS	NS	NS
Mimic Shiner	Nat, Int, Ins, Veg, Cyp	X	NS		NS	NS	NS	NS
Mottled Sculpin	Nat, Int, Ins, Smb							NS
Northern Pike	Nat, TC, Veg	X	GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	GN, TN	NS, GN, TN
Northern Redbelly Dace	Nat, Veg, Cyp		NS					
Pugnose Shiner	Nat, Int, Ins, Veg, Cyp					NS	NS	NS
Pumpkinseed	Nat, Ins	X	NS, GN, TN	NS, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Rock Bass	Nat, Int, TC	X	NS, GN, TN	NS, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Smallmouth Bass	Nat, Int, TC						NS, GN, TN	
Spottail Shiner	Nat, Ins, Cyp	X	NS			NS	NS	NS
Tadpole Madtom	Nat, Ins, Smb, Veg	X				NS		NS
Walleye	Nat, TC	X	GN, TN	GN, TN	NS, GN, TN	GN, TN	GN, TN	NS, GN, TN
Weed Shiner	Nat, Veg, Cyp					NS	NS	
Western Blacknose Dace	Nat, Ins, Smb, Cyp							
White Sucker	Nat, Omn	X	GN, TN	GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Yellow Bullhead	Nat, Omn	X	NS, GN, TN	GN, TN	GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Yellow Perch	Nat, Ins	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN

[1] Sampling methods that the species were captured with are abbreviated as follows: NS=Backpack Electrofishing and Seining, GN=Gillnetting, and TN=Trap Netting.
[2] Tolerance, feeding, and habitat guilds are abbreviated as follows: Nat=Native, Int=Intolerant, Tol=Tolerant, Ins=Insectivore, Omn=Omnivore, TC=Top Carnivore, Smb=Small Benthic Dweller, Veg=Vegetative Dweller, and Cyp=Cyprinid. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

Table 7. Comparison of common fish species (occurring in 50% or more of lakes) captured[1] in OTRW lakes assessed as fully supporting aquatic life use (marked with an "X" in the tool 4 column) relative to species captured in respective vulnerable and impaired lakes that were scored with fish index of biological integrity (FIBI) tool 4.

Species	Tolerance, feeding, and/ habitat guild[2]	FIBI tool 4	Acorn 03-0258-00	Eagle 03-0265-00	Middle Cormorant 03-0602-00	Walker 56-0310-00	Anna 56-0448-00
Banded Killifish	Int, Ins, Veg	X	NS	NS	NS	NS	
Black Bullhead	Tol, Omn	X	NS		GN	NS, GN, TN	GN, TN
Black Crappie	TC	X	GN, TN	GN, TN	GN, TN	NS, GN, TN	NS, GN, TN
Blackchin Shiner	Int, Ins, Veg	X	NS	NS	NS	NS	
Blacknose Shiner	Int, Ins, Veg	X		NS	NS	NS	
Bluegill	Ins	X	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN
Bluntnose Minnow	Omn	X	NS	NS	NS	NS	NS
Bowfin	TC, Veg		NS, GN, TN			NS, GN, TN	
Brook Stickleback	Ins		NS				
Brown Bullhead	Omn	X	GN, TN	GN	GN, TN	GN, TN	GN, TN
Central Mudminnow	Ins, Veg		NS		NS		
Cisco	Int, Ins						
Common Carp	Tol, Omn		TN		GN, TN	TN	NS, GN, TN
Fathead Minnow	Tol, Omn		NS		NS		
Golden Shiner	Ins	X	TN		NS	NS	
Green Sunfish	Tol, Ins	X		NS, TN	NS, TN		NS
Hornyhead Chub	Ins			NS			
Iowa Darter	Int, Ins, Smb, Veg	X	NS	NS	NS	NS	NS
Johnny Darter	Ins, Smb	X	NS	NS	NS	NS	NS
Largemouth Bass	TC	X	NS, GN	NS, GN, TN	NS, GN, TN	NS, GN, TN	NS, GN, TN

Species	Tolerance, feeding, and/ habitat guild[2]	FIBI tool 4	Acorn 03-0258-00	Eagle 03-0265-00	Middle Cormorant 03-0602-00	Walker 56-0310-00	Anna 56-0448-00
Logperch	Int, Ins, Smb					NS	
Mimic Shiner	Int, Ins, Veg				NS	NS	
Mottled Sculpin	Int, Ins, Smb		NS				
Northern Pike	TC, Veg	X	NS, GN, TN	GN, TN	NS, GN, TN	NS, GN, TN	GN
Pugnose Shiner	Int, Ins, Veg				NS		
Pumpkinseed	Ins	X	GN, TN	NS, GN, TN	NS, GN, TN	NS, TN	
Rock Bass	Int, TC	X			NS, GN, TN	NS, TN	
Smallmouth Bass	Int, TC					NS	
Spottail Shiner	Ins	X	NS	NS	NS	NS	NS
Tadpole Madtom	Ins, Smb, Veg	X	NS		NS		
Walleye	TC	X	GN, TN	GN, TN	GN, TN	NS, GN, TN	GN, TN
Weed Shiner	Veg						
White Sucker	Omn	X	NS, GN		GN	NS, GN, TN	GN, TN
Yellow Bullhead	Omn	X	TN	NS, GN, TN	NS, GN, TN	NS, GN, TN	GN, TN
Yellow Perch	Ins	X	NS, GN, TN	NS, GN	NS, GN, TN	NS, GN	NS, GN, TN

[1] Sampling methods that the species were captured with are abbreviated as follows: NS=Backpack Electrofishing and Seining, GN=Gillnetting, and TN=Trap Netting.
[2] Tolerance, feeding, and habitat guilds are abbreviated as follows: Int=Intolerant, Tol=Tolerant, Ins=Insectivore, Omn=Omnivore, TC=Top Carnivore, Smb=Small Benthic Dweller, and Veg=Vegetative Dweller. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

Table 8. Comparison of common fish species (occurring in 50% or more of lakes) captured in OTRW lakes assessed as fully supporting aquatic life use (marked with an "X" in the tool 7 column) relative to species captured in respective vulnerable and impaired lakes that were scored with fish index of biological integrity (FIBI) tool 7.

Species	Tolerance, feeding, and/or habitat guild	FIBI tool 7	Fish 56-0684-00
Banded Killifish	Ins, Veg	X	NS
Black Bullhead	Tol	X	NS, GN, TN
Black Crappie	TC	X	NS, GN, TN
Blackchin Shiner	Ins, Veg	X	
Blacknose Shiner	Ins, Veg	X	
Bluegill	Ins	X	NS, GN, TN
Bluntnose Minnow		X	NS
Bowfin	TC, Veg	X	TN
Brook Stickleback	Ins	X	NS
Brown Bullhead		X	TN
Central Mudminnow	Ins, Veg	X	
Cisco	Ins	X	
Common Carp	Tol		NS, GN, TN
Fathead Minnow	Tol	X	NS
Golden Shiner	Ins	X	NS
Green Sunfish	Tol, Ins	X	
Iowa Darter	Ins, Smb, Veg	X	NS
Johnny Darter	Ins, Smb	X	NS
Largemouth Bass	TC	X	NS, GN, TN
Logperch	Ins, Smb		
Mimic Shiner	Ins, Veg	X	
Northern Pike	TC, Veg	X	NS, GN, TN
Pumpkinseed	Ins	X	NS, GN, TN
Rock Bass	TC	X	TN
Smallmouth Bass	TC	X	
Spottail Shiner	Ins	X	NS

Species	Tolerance, feeding, and/or habitat guild	FIBI tool 7	Fish 56-0684-00
Tadpole Madtom	Ins, Smb, Veg	X	NS
Walleye	TC	X	GN, TN
Weed Shiner	Veg	X	
White Sucker		X	NS, GN
Yellow Bullhead		X	GN, TN
Yellow Perch	Ins	X	NS, GN

[1] Sampling methods that the species were captured with are abbreviated as follows: NS=Backpack Electrofishing and Seining, GN=Gillnetting, 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=Vegetative 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 OTRW

3.1. Candidate causes

Eutrophication

Land use disturbance and excess nutrients such as total phosphorus (TP) have been identified as causes of eutrophication in lakes. Water quality measurements taken in the OTRW lakes assessed for aquatic life use indicate that TP averages 19.2 parts per billion (ppb) and varies from 8.2 ppb to 38.0 ppb (Table 10.). Similarly, land use disturbance in the upstream watersheds averages 37.9% and varies from 2.6% to 67.7% (Table 10.). Forty eight percent 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). Seven percent of the lakes assessed by MPCA for aquatic recreation within the OTRW are impaired based on MPCA's nutrient water quality standards (Minn. R. Ch. 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 OTRW.

Physical habitat alteration

MNDNR Score the Shore (StS) data (Perleberg et al. 2019) indicates that lakes within the OTRW have more riparian shoreline disturbance on average than lakes statewide, although lakes were not selected at random. The average StS score for lakes within the OTRW was 71, which is lower than the statewide average of 73 (Table 10.). Likewise, the average scores for developed and undeveloped sites in the OTRW were 60 and 92, respectively. The score for developed sites was slightly lower than the statewide average of 63. "Low" StS scores are indicative of disturbed riparian lakeshore habitat whereas "high" StS scores are indicative of relatively undisturbed riparian lakeshore habitat (Perleberg et al. 2019; Table 9.). Results indicate that habitat loss from riparian lakeshore development may be higher on lakes within the OTRW than lakes statewide. An alternative measure, dock density (based on Google imagery from 2015-2019), can also be used to evaluate the level of disturbance 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). Of the 86 lakes in the OTRW that were assessed for aquatic life use, 55% had dock densities exceeding 16 docks per mile. Dock density averaged 19.6 docks per mile and varied from 0.4 to 52.5 docks per mile (Table 10.). Therefore, riparian lakeshore development will be evaluated further as a potential stressor within the OTRW.

Table 9. 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

A review of MNDNR Permitting and Reporting System (MPARS) information indicates that permits have been and are currently issued to mechanically and chemically remove emergent, floating-leaf, and submerged plants on at least 155 lakes within the OTRW. Additional removal of submerged plants outside of the date range of available permit data, removal that does not require a permit, and illegal removal of plants has also occurred within the OTRW.

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, Curly-leaf Pondweed, Flowering Rush, Purple Loosestrife, Rusty Crayfish, and Zebra Mussels—are present in a subset of lakes within the OTRW.

A review of the Minnesota inventory of dams indicates that there are 64 dams located within the OTRW; 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 OTRW scores 44 out of a possible 100, whereas the statewide average is 53. Preliminary data from a MNDNR culvert inventory is also available for culverts that have been assessed to date. Of the 194 culverts that have been evaluated in the OTRW, 44% create a possible barrier to fish passage at some flows due to their size, function, or design (A. Hillman, MNDNR, unpublished data).

A review of sedimentation data indicates that measures such as total suspended solids or substrate embeddedness are lacking for most lakes within the OTRW. 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 OTRW.

Altered interspecific competition

A review of MNDNR survey data indicates that the OTRW is affected by non-native species that can directly compete with native fish species for resources. At least 57 of the 86 assessed lakes within the watershed contain Zebra Mussels and/or Common Carp, both of which have the potential to directly compete with native fishes, as well as several other non-invasive plants.

A review of gamefish management activities indicates that stocking and harvest regulations occur in many lakes within the OTRW. 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.

Temperature regime changes

A review of research by Jacobson et al. (2017) indicates that mean annual lake-specific air temperatures within the OTRW may have increased by an average of 1.9 °F over the last century as a result of climate change, which is 0.6 °F warmer than for other lakes included in the statewide dataset. Increases in lake-specific air temperature have been shown to be correlated with increases in water temperature

(Robertson and Ragotzkie 1990). Although modeling evidence suggests that water temperature has increased in lakes within the OTRW, limited research is available to demonstrate the magnitude of change needed to result in changes to the fish community as indicated by the FIBI. Despite this, temperature regime changes will be evaluated as a potential stressor for several impaired and vulnerable lakes that contain or have historically contained coldwater species such as Cisco or Burbot (i.e., Walker, Little McDonald, Big McDonald, Jewett, Toad, Little Toad, Acorn, Cotton, Sallie, Big Cormorant, and Star lakes). Both of these species prefer temperatures below 68 °F and dissolved oxygen (DO) concentrations above 3 parts per million (ppm) (Frey 1955; Jacobson et al 2010). When these conditions are not met simultaneously, habitat becomes limited for these species, and this most frequently can occur during the summer months.

Decreased dissolved oxygen

Data regarding DO 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 summer or winterkill events. As such, limited information exists to indicate whether DO concentrations are changing in a manner that might result in changes to fish communities, and specifically cool- and warmwater species, in the OTRW. Despite this, decreased DO will be evaluated as a potential stressor for several impaired and vulnerable lakes that contain or have historically contained coldwater species such as Cisco or Burbot (i.e., Walker, Little McDonald, Big McDonald, Jewett, Toad, Little Toad, Acorn, Cotton, Sallie, Bit Cormorant, and Star lakes). Both of these species prefer DO concentrations above 3 ppm and temperatures below 68 °F (Frey 1955; Jacobson et al 2010). When these conditions are not met simultaneously, habitat becomes limited for these species, and this most frequently can occur during the summer months.

3.2. Eliminated causes

Increased ionic strength

A review of MPCA's Impaired Waters List indicates that no lakes within the OTRW were assessed as impaired for aquatic life use based on the chronic standard for chloride (MPCA 2018a). 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 OTRW.

Pesticide application

A review of Minnesota Department of Agriculture (MDA) incident reports indicated the occurrence of several small spills within the OTRW (MDA 2016); however, the quantity and proximity of chemical contamination to any lake assessed would not likely impact the fish communities present. MDA also conducts sampling to monitor surface waters for pesticides. A summary of monitoring data from the 2012 National Lakes Assessment concluded that pesticide levels detected in lakes in the OTRW were below applicable water quality standards and reference values (Tollefson et al. 2014).

Metal contamination

A review of MPCA's Impaired Waters List indicates that the OTRW contains 40 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 EPA 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 OTRW.

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 OTRW (e.g., Detroit Lakes, Fergus Falls, and Perham), and that they were not likely a significant stressor to fish communities (MPCA 2018b).

Table 10. Summary of watershed and shoreline stressor information for the 86 OTRW 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]
03-0107-00	Toad	2	IF-Vuln	14.6	26.3	13.4	75
03-0136-00	Juggler	2	FS	4.5	10.1	9.5	84
03-0153-00	Island	2	FS	6.3	19.8	10.6	84
03-0155-00	Round	2	FS	2.6	17.4	16.6	87
03-0158-00	Many Point	2	FS	2.7	14.8	3.7	87
03-0159-00	Elbow	2	FS	3.2	14.9	12.3	82
03-0166-00	Hungry	4	FS	26.6	21.1	1.8	84
03-0189-00	Little Toad	2	IF-Vuln	37.1	22.9	14.4	72
03-0195-00	Height of Land	7	FS	4.2	33.3	5.5	75
03-0234-00	Little Bemidji	2	FS	3.2	13.3	6.1	87
03-0258-00	Acorn	4	FS-Vuln	30.6	21.6	9.1	78
03-0265-00	Eagle	4	NS	37.0	17.4	9.9	83
03-0286-00	Cotton	2	FS-Vuln	17.7	18.8	20.6	65
03-0287-00	Pickerel	2	FS	21.2	14.4	15.0	85
03-0355-00	Sauer	4	FS	37.7	23.1	6.4	N/A
03-0357-00	Munson	4	FS	51.3	18.1	33.2	63
03-0359-00	Sallie	2	FS-Vuln	41.5	29.7	29.0	66
03-0381-00	Detroit	2	FS	39.4	20.4	39.8	50
03-0383-00	Long	2	FS	49.1	11.3	32.2	60
03-0386-00	Little Floyd	4	FS	41.5	25.5	36.7	59
03-0387-00	Floyd	2	FS	41.8	15.5	34.2	62
03-0475-00	Melissa	2	FS	39.8	19.7	52.5	46

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]
03-0486-00	Pearl	5	FS	50.3	26.5	18.6	72
03-0500-00	Maud	4	FS	41.7	17.6	31.6	67
03-0503-00	Eunice	4	FS	43.9	13.5	43.4	56
03-0506-00	Little Cormorant	2	NS	39.8	36.8	9.9	73
03-0575-00	Leif	5	FS	45.8	34.8	27.4	65
03-0576-00	Big Cormorant	2	FS-Vuln	39.5	14.5	34.2	67
03-0582-00	Ida	5	FS	50.5	31.7	37.6	56
03-0588-00	Upper Cormorant	2	NS	49.3	33.3	11.3	79
03-0602-00	Middle Cormorant	4	NS	45.8	16.5	43.2	51
03-0638-00	Bijou	5	IF	48.2	38.0	14.1	73
15-0108-00	Pickerel	4	FS	5.9	8.8	7.4	N/A
56-0130-00	Big Pine	2	FS	29.3	35.7	23.0	66
56-0138-00	East Battle	2	FS	53.0	14.9	20.2	N/A
56-0141-00	Rush	2	FS	34.4	30.2	24.8	63
56-0142-00	Little Pine	2	FS	23.1	24.3	33.4	50
56-0191-00	Stuart	2	FS	51.0	13.1	12.6	83
56-0193-00	Ethel	2	FS	54.5	10.7	15.6	70
56-0209-00	Buchanan	7	FS	56.4	19.6	20.2	N/A
56-0238-00	Clitherall	2	FS	63.0	10.6	19.2	N/A
56-0239-00	West Battle	2	IF	53.8	12.2	31.6	N/A
56-0240-00	Blanche	2	FS	52.2	14.3	21.3	76
56-0241-00	Annie Battle	4	FS	53.4	N/A	0.4	N/A
56-0243-00	Marion	2	FS	46.4	22.9	29.0	N/A
56-0245-00	Devils	2	IF	50.3	14.7	24.2	N/A
56-0298-00	Deer	4	FS	37.5	18.8	22.6	N/A
56-0302-01	First Silver	4	FS	61.1	19.2	33.1	N/A
56-0303-00	Molly Stark	4	FS	53.9	10.1	2.7	88
56-0310-00	Walker	4	NS	34.7	36.0	11.9	82
56-0328-00	Little McDonald	2	NS	50.9	8.2	19.5	60
56-0335-00	Paul	2	NS	67.7	12.7	21.2	69
56-0358-00	Scalp	2	FS	22.8	9.6	34.5	N/A
56-0360-00	Rose	2	FS	26.8	13.9	16.1	N/A
56-0378-00	East Lost	4	FS	37.5	14.5	19.6	72
56-0383-00	Dead	7	FS	33.2	23.4	8.9	80
56-0385-00	Star	2	FS-Vuln	31.7	18.1	9.5	76
56-0386-01	Big McDonald	2	NS	32.2	15.0	22.3	70
56-0386-02	West McDonald	2	FS	50.1	9.7	34.2	52

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]
56-0387-00	Sybil	2	FS	40.1	10.4	20.8	79
56-0388-02	Long (main lake)	2	FS	40.4	21.2	15.8	75
56-0448-00	Anna	4	NS	62.9	13.9	3.5	84
56-0449-00	Pleasant	4	FS	61.0	19.5	5.9	N/A
56-0475-00	Pickerel	2	FS	50.4	11.9	37.5	N/A
56-0476-00	Maine (Round)	4	IF	50.4	14.2	2.3	N/A
56-0481-00	West Lost	5	FS	38.4	18.6	4.7	87
56-0501-00	East Spirit	2	FS	41.6	11.9	17.8	N/A
56-0517-00	East Silent	2	FS	24.6	10.6	19.5	N/A
56-0519-00	West Silent	2	NS	24.5	10.6	15.8	78
56-0523-00	East Loon	2	FS	37.4	12.7	14.1	80
56-0532-00	Leek	2	FS	22.4	18.9	17.1	N/A
56-0570-00	Bass	5	IF	62.6	34.4	7.7	79
56-0658-00	Wall	4	FS	62.6	25.4	25.9	N/A
56-0684-00	Fish	7	NS	61.2	32.0	4.3	90
56-0695-00	Heilberger	5	FS	26.9	14.0	15.3	N/A
56-0724-00	Beers	2	IF	11.7	14.1	0.7	N/A
56-0747-01	North Lida	2	FS	30.8	18.2	29.0	62
56-0747-02	South Lida	2	FS	30.8	32.6	12.0	77
56-0749-00	Crystal	2	FS	20.4	18.6	23.5	N/A
56-0759-00	Franklin	2	FS	22.9	21.4	13.9	N/A
56-0760-01	Lizzie (north portion)	2	FS	39.0	14.2	26.3	67
56-0784-00	Long	2	IF	37.0	19.0	18.0	N/A
56-0786-00	Pelican	2	FS	40.6	15.2	50.7	48
56-0829-00	Pebble	4	FS	64.4	21.1	7.4	67
56-0877-00	Jewett	2	NS	42.2	19.9	37.1	52
56-0915-00	Prairie	7	FS	39.6	21.1	15.1	N/A

[1] "FS" indicates fully supporting aquatic life use, "IF" indicates insufficient information, "NS" indicates not supporting aquatic life use, 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 2015–2019.
[5] Score the Shore scores (Perleberg et al. 2019) assess the quantity and integrity of lakeshore habitat.

4. Evaluation of candidate causes in impaired lakes

Twelve lakes were assessed as not supporting aquatic life use because they had FIBI scores that were below the impairment threshold (Table 4). These lakes include Eagle (03-0265-00), Little Cormorant (03-0506-00), Upper Cormorant (03-0588-00), Middle Cormorant (03-0602-00), Walker (56-0310-00), Little McDonald (56-0328-00), Paul (56-0335-00), Big McDonald (56-0386-01), Anna (56-0448-00), West Silent (56-0519-00), Fish (56-0684-00), and Jewett (56-0877-00). Causes of stress to the fish communities in these impaired lakes are evaluated.

4.1. Eagle Lake (DOW 03-0265-00)

Eagle Lake is 320 acres in size and has a maximum depth of 29-feet. The littoral zone of the lake covers 44% of the lake area. Eagle Lake is scored with FIBI tool 4. Lakes scored with this tool are characterized as generally deep with simple (i.e., round) shorelines, less than 80% littoral area, and moderate species richness (Table 1).

Eutrophication has been identified as an inconclusive stressor to aquatic life use in Eagle Lake and will be evaluated further. Conversely, physical habitat alteration and altered interspecific competition have been eliminated as primary stressors (Figure 3. Eagle Lake (03-0265-00) fish community and stressors; based on fish index of biological integrity (FIBI) results). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Eagle Lake was sampled using seining and backpack electrofishing during July 2017 and gill netting and trap netting during August 2017. The health of the fish community was evaluated using these data and FIBI tool 4. 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 eleven fish community diversity and composition metrics for tool 4 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 33 was below the impairment threshold (38) developed for lakes that are similar to Eagle Lake (Table 3).

During the 2017 FIBI survey, 18 fish species were captured (Table 7). The proportion of biomass from top carnivores (i.e., 41% Black Crappie, Largemouth Bass, Northern Pike, and Walleye) in the gill nets and the proportion of small benthic dwelling species (i.e., 2% Iowa Darter and Johnny Darter) in the nearshore gears (i.e., seining and backpack electrofishing) were below levels expected for similar lakes as indicated by the respective FIBI metrics. Four intolerant species, one tolerant species, two small benthic dwelling species, and five vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 4 include Golden Shiner, Rock Bass, and Tadpole Madtom that positively affect several FIBI metric scores and Black Bullhead and White Sucker that negatively affect an FIBI metric score (Table 7).

Because this is the first time utilizing the 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 Eagle Lake. One Common Shiner was sampled in a MNDNR Fisheries survey in 1983, two Creek Chubs were sampled in

1969, and several Golden Shiners were sampled in 1983 and 1992, but these species have not been observed in MNDNR surveys since that time (MNDNR 2018c). These historically sampled species may be represented by only one or two occurrences and identification confirmation cannot occur due to the lack of vouchered specimens.

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Eagle Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data (i.e., June–September 2009–2018) collected and summarized by MPCA indicates that mean TP is 17.4 ppb (N=12), chlorophyll-a is 5.9 ppb (N=12), and Secchi transparency is 10.0 feet (N=12) in Eagle Lake. These parameters indicate that excess nutrients may not be the primary cause of stress to the fish community.

Nonetheless, of the 1,507 acres within the contributing watershed, 37.0% is classified as unnatural land cover (i.e., 29.2% agricultural and 7.8% developed). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 89% of the agricultural land within Eagle Lake's contributing watershed is hay and pasture land whereas 11% is cultivated. Additionally, one small feedlot is also located within the shoreland (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Eagle Lake. Land along the north shore that was historically managed as pasture and agricultural land has since been converted to high use RV park. In 2001, individual sewage treatment systems on 59 parcels surrounding the lake were inventoried and 17 were deemed non-compliant (BSWCD 2014). When compliance was last evaluated in 2004, all but two had been updated. Therefore, parcels surrounding the lake should be prioritized for future inspections to ensure compliance is met and maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Eagle Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 4.7:1. As such, management actions intended to minimize nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Undeveloped lands, particularly parcels in public ownership that are protected from future development, can 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. Several examples include AMAs and Wildlife Management Areas (WMAs) that are managed by the state, but neither occur within Eagle Lake's contributing watershed.

Physical habitat alteration

Physical habitat alteration does not appear to be occurring at a level that may be negatively affecting the fish community in Eagle Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 83, is moderate within Eagle Lake and above the statewide average score of 73. A moderate score indicates that on average surveyed sites have a high percentage of unaltered habitat but that at least one zone (i.e., shoreland, shoreline, or aquatic) has lower habitat quality than a high scoring site. Developed sites that generally retain a high percentage of natural habitat areas may score in this range. In this case, development has had a relatively uniform effect on all habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of Aquatic Management Areas (AMAs); however, none exist on Eagle Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an Aquatic Plant Management (APM) permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Eagle Lake. According to MPARS, at least four properties are permitted to remove submersed plants via automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 36 docks (9.9 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate.

Chinese Mystery Snails and Curly-leaf Pondweed, two non-native species, are present in Eagle Lake. No significant changes to the physical habitat resulting from their presence have been documented.

The water level in Eagle Lake is unregulated (i.e., no water control structure) and has varied by 1.9 feet between 1947–2017 (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 Eagle Lake and therefore the FIBI score.

Altered interspecific competition

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

To date, Chinese Mystery Snails and Curly-leaf Pondweed have been the only documented non-native species in the lake, and direct competition with the native fish community is unlikely.

Historically, Eagle Lake had been stocked with Northern Pike, sunfish, Largemouth Bass, Black Crappie, and Walleye. Prior to 2014, Walleye fry were stocked annually at a rate of 1,000 per littoral acre. From 2014 to present, Walleye fingerlings have been stocked at a rate of 2.0 pounds per littoral acre in even numbered years per the 2014 lake management plan (MNDNR, unpublished data). Most Minnesota lakes that are stocked with Walleyes receive an average of 1,000 fry annually or 2.0 pounds of fingerlings biennially per littoral acre. 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.

Relative abundance of adult Walleye in Eagle Lake has been quite variable but is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 Eagle Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. Nonetheless, 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. Some commercial harvest of White Sucker and bullheads also occurred in the 1980s, but this has likely had little effect on current fish community structure.

Figure 3. Eagle Lake (03-0265-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Eagle Lake (03-0265-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 33 (5 points below impairment threshold for similar lakes)
  - Species sampled that negatively affect the FIBI score: Brown Bullhead, Green Sunfish, Yellow Bullhead, Bluntnose Minnow
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Hornyhead Chub, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Pumpkinseed, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Common Shiner, Creek Chub, Golden Shiner
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 17.4 ppb mean total phosphorus, 37% of contributing watershed classified as unnatural land cover
- **Eliminated Causes:**
  - Physical habitat alteration: moderate dock density of 9.9 docks per mile of shoreline, moderate lakewide Score the Shore (StS) habitat score of 83, Curly-leaf Pondweed present, some permitted aquatic plant removal activity, no significant inlets or outlets
  - Altered interspecific competition: Curly-leaf Pondweed and Chinese Mystery Snails present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - No candidate cause identified, the lack of connectivity, whether natural or unnatural, could be influencing the fish community
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover

4.2. Little Cormorant Lake (DOW 03-0506-00)

Little Cormorant Lake is 1,067 acres in size and has a maximum depth of 34 feet. The littoral zone of the lake covers 58% of the lake area. Little Cormorant Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life use in Little Cormorant Lake and will be evaluated further. Conversely, physical habitat alteration has been identified as an inconclusive stressor and altered interspecific competition has been eliminated as a primary stressor (Figure 4). Additionally, Little Cormorant Lake is occasionally vulnerable to partial winterkill events during severe winters. A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Little Cormorant Lake was sampled using seining and backpack electrofishing during July 2016 and gill netting and trap netting during June 2012. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score, composed of fifteen fish community diversity and composition metrics for tool 2 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 26 was below the impairment threshold (45) developed for lakes that are similar to Little Cormorant Lake (Table 3). An additional nearshore survey was completed in June 2012, but it will not be discussed because it received insufficient sampling effort due to dense vegetation limiting the sampling area.

During the FIBI survey, 15 fish species were captured (Table 5**Error! Reference source not found.**). The d iversity of cyprinid (i.e., Golden Shiner and Spottail Shiner) and small benthic dwelling species were below levels expected for similar lakes as indicated by the respective FIBI metrics. One intolerant species, two tolerant species, no small benthic dwelling species, and two vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Banded Killifish, Blackchin Shiner, Blacknose Shiner, Bluntnose Minnow, Bowfin, Fathead Minnow, Iowa Darter, Johnny Darter, Logperch, Mimic Shiner, Tadpole Madtom, and Yellow Bullhead (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, however, neither backpack electrofishing nor seining using the FIBI protocols occurred prior to 2012 to document the nongame fish species present in Little Cormorant Lake (MNDNR 2018c). Only one additional species, Tadpole Madtom, was captured in the 2012 nearshore survey.

Data analysis/Evaluation for each candidate cause

Eutrophication

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

Recent water quality data collected and summarized by MPCA indicates that mean TP is 36.8 ppb (N=49), chlorophyll-a is 13.3 ppb (N=46), and Secchi transparency is 6.1 feet (N=108) in Little Cormorant Lake. These parameters indicate that the lake is likely receiving inputs of excess nutrients that could negatively affect the fish community.

Of the 3,052 acres within the contributing watershed, 39.8% is classified as unnatural land cover (i.e., 33.8% agricultural and 6.0% developed). The percentage of unnatural land cover nearly exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 64% of the agricultural land within Little Cormorant Lake's contributing watershed is cultivated whereas 36% is hay and pasture land. No feedlots are located within the contributing watershed. Surface runoff from agricultural land 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 Little Cormorant Lake. In 1998, individual sewage treatment systems on 50 parcels surrounding the lake were inventoried and 24 were deemed non-compliant (BSWCD 2014). More recently, 322 parcels were evaluated in 2008 and all have been deemed compliant (K. Vareberg, Becker County Zoning, personal communication). Runoff from lawns and discharge from failing individual sewage treatment systems could be contributing excess nutrients into the lake.

Little Cormorant Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 2.9:1. As such, management actions intended to reduce excess nutrient inputs should be relatively targeted and reasonably attainable.

Although a high percentage of land is classified as unnatural, one AMA does exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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 and eliminated 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 Little Cormorant Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 73, is moderate within Little Cormorant Lake and equal to the statewide average. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. The lake management plan indicates that the number of homes and cabins on the lake has increased by 590% between 1977 (N=20) to 1992 (N=138) and that shoreline development continues (MNDNR, unpublished data). This plan emphasized the need to retain critical undeveloped shoreline areas for their value as riparian wetlands. One effective way to protect shoreline is through acquisition of AMAs. Several AMAs totaling 14 acres exist on Little Cormorant Lake that protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Little Cormorant Lake. According to MPARS, at least 38 properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. A 2012 survey has documented 210 acres of floating-leaf and emergent vegetation, but no historic surveys of similar rigor have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 235 docks (9.9 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate and the relatively large area of floating-leaf and emergent vegetation.

Curly-leaf Pondweed, a non-native species, is present in Little Cormorant Lake. No significant changes to the physical habitat resulting from its presence have been documented.

The water level in Little Cormorant Lake is unregulated (i.e., no water control structure) and has varied by 3.8 feet between 1975–2017 (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 Little Cormorant Lake and therefore the FIBI score.

Altered interspecific competition

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

To date, Curly-leaf Pondweed has been the only documented non-native species in the lake, and direct competition with the native fish community is unlikely.

Historically, Little Cormorant Lake had been stocked with Bluegill, Black Crappie, Largemouth Bass, Northern Pike, Fathead Minnow, Yellow Perch, and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 1,000 per littoral acre annually, as described in the 2014 lake management plan (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.

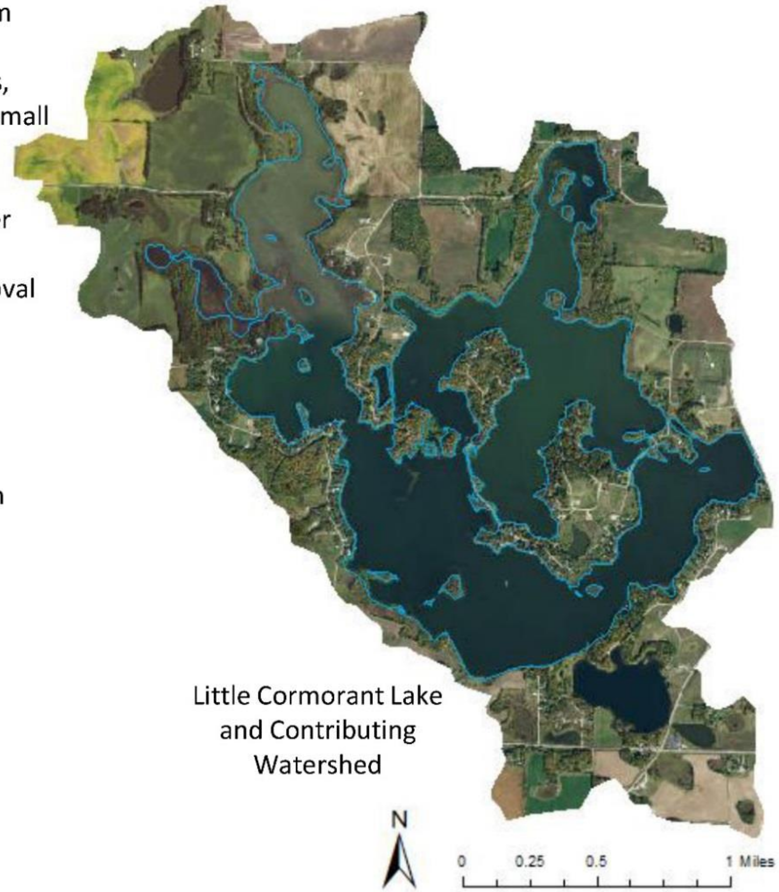
Relative abundance of adult Walleye in Little Cormorant Lake has been relatively consistent and is currently lower than the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye because of stocking (MNDNR, unpublished data).

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 Little Cormorant Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. However, special regulations were initiated in 2008 in an attempt to increase size structure of sunfish, Black Crappie, and Walleye. Some commercial harvest of bullheads also occurred between 1959 and 2004, but this has likely had little effect on current fish community structure.

Figure 4. Little Cormorant Lake (03-0506-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Little Cormorant Lake (03-0506-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 26 (19 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Brown Bullhead, Green Sunfish, White Sucker
  - Species sampled that positively affect the FIBI score: Black Crappie, Bluegill, Central Mudminnow, Golden Shiner, Largemouth Bass, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Tadpole Madtom
- **Candidate Causes:**
  - Eutrophication (excess nutrients): 36.8 ppb mean total phosphorus, 40% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 2.9:1
- **Inconclusive Causes:**
  - Physical habitat alteration: moderate dock density of 9.9 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 73, Curly-leaf Pondweed present, some permitted aquatic plant removal activity, no significant inlets or outlets
- **Eliminated Causes:**
  - Altered interspecific competition: Curly-leaf Pondweed present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Use best management practices to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover
  - The lack of connectivity, whether natural or unnatural, could be influencing the fish community



4.3. Upper Cormorant Lake (DOW 03-0588-00)

Upper Cormorant Lake is 927 acres in size and has a maximum depth of 29-feet. The littoral zone of the lake covers 51% of the lake area. Upper Cormorant Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Eutrophication has been identified as a likely stressor to aquatic life use in Upper Cormorant Lake and will be evaluated further. Conversely, physical habitat alteration and altered interspecific competition 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 Upper Cormorant Lake was sampled using seining and backpack electrofishing during August 2012 and July 2017 and gill netting and trap netting during August 2012 and 2017. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI scores of 42, 35, and 27 were below the impairment threshold (45) developed for lakes that are similar to Upper Cormorant Lake (Table 3). An additional nearshore survey was completed in August 2008, but it received insufficient sampling effort based on FIBI protocols and will not be discussed.

During the FIBI surveys, 27 fish species were captured (Table 5). The proportion of biomass from tolerant species (i.e., 11–24% Common Carp and Green Sunfish) in the trap nets and the relatively high diversity of omnivores (i.e., Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, and Yellow Bullhead) exceeded levels expected for similar lakes as indicated by the respective FIBI metrics. Six intolerant species, four tolerant species, four small benthic dwelling species, and eight vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Bowfin, Mimic Shiner, and Rock Bass. Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 has been sampled in Upper Cormorant Lake. Rock bass were sampled in one MNDNR Fisheries survey in 1976, but they have not been observed in MNDNR surveys since that time (MNDNR 2018c). Likewise, neither backpack electrofishing nor seining using FIBI protocols occurred prior to 2008 to document the nongame fish species present. Only one additional species, Mimic Shiner, was captured in the 2008 nearshore survey.

Data analysis/Evaluation for each candidate cause

Eutrophication

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

Recent water quality data collected and summarized by MPCA indicates that mean TP is 33.3 ppb (N=35), chlorophyll-a is 16.9 ppb (N=35), and Secchi transparency is 7.3 feet (N=164) in Upper Cormorant Lake. These parameters indicate that the lake is likely receiving inputs of excess nutrients that could negatively affect the fish community.

Of the 9,224 acres within the contributing watershed, 49.3% is classified as unnatural land cover (i.e., 44.4% agricultural, 4.4% developed, and 0.4% barren). 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). The land use disturbance in the contributing watershed has also likely contributed to the relatively high nutrient levels (i.e., 52.9 ppb TP) in Rossman Lake, which is upstream of Upper Cormorant Lake.

Approximately 52% of the agricultural land within Upper Cormorant Lake's contributing watershed is hay and pasture land whereas 48% is cultivated. No feedlots are located within the contributing watershed. Surface runoff from agricultural land 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 Upper Cormorant Lake. In 1996, individual sewage treatment systems on 199 parcels surrounding the lake were inventoried and 61 were deemed non-compliant (BSWCD 2014). Conversely, 195 parcels were evaluated in 2008 and all were deemed compliant at that time (K. Vareberg, Becker County Zoning, personal communication). Runoff from lawns and discharge from failing individual sewage treatment systems could be contributing excess nutrients into the lake.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Upper Cormorant Lake, as indicated by a watershed-to-lake ratio of 9.5:1. The combination of a 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 AMAs and Waterfowl Production Areas (WPAs) do exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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 Upper Cormorant Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 79, is moderate within Upper Cormorant Lake and above the statewide average score of 73. Development has had a relatively uniform effect on the shoreland, shoreline, and aquatic habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. Several parcels totaling 131 acres are included in Upper Cormorant AMA that protect vulnerable shoreline on the northwest end of the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Upper Cormorant Lake. According to MPARS, at least 17 properties are, or have been, permitted to remove submersed and emergent plants via pesticide application, mechanical removal, or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. A 2016 survey has documented 98 acres of floating-leaf and emergent vegetation, but no historic surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 146 docks (11.3 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate and the relatively large area of floating-leaf and emergent vegetation.

Zebra Mussels, Curly-leaf Pondweed, and Common Carp, three non-native species are present in Upper Cormorant Lake. Zebra Mussels were first found in 2019, therefore densities at the time of assessment were likely negligible and would not have had an effect on the fish community at that time. No significant changes to the physical habitat resulting from the presence of Curly-leaf Pondweed have been documented. Similarly, Common Carp have been present at low densities since the 1970s but there is no direct evidence that they are affecting water quality or native fish populations, per the lake management plan (MNDNR, unpublished data). At high densities, these species have the potential to directly compete with native fish for resources.

The water level in Upper Cormorant Lake is unregulated (i.e., no water control structure) and has varied by 3.9 feet between 1963–2017 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., County Highway 1 and several field crossings) are present upstream of the inlet, which ultimately connects Upper Cormorant Lake to Bijou Lake. Similarly, several crossings (i.e., Golden Lane, Swanies Creek Road, County Highway 5, South Big Cormorant Road, and several unnamed crossings) occur downstream of the outlet, which ultimately connects Upper Cormorant Lake to Nelson, Middle Cormorant, and Big Cormorant lakes). One additional culvert further downstream at the connection with Pelican Lake (i.e., County Highway 9) has been identified as a potential barrier as cattails may be blocking passage (A. Hillman, MNDNR, unpublished data). These crossings should be investigated to determine their potential as barriers to fish passage. If these crossings are determined to act as barriers, actions should be considered to restore connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Upper Cormorant Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Zebra Mussels, Curly-leaf Pondweed, and Common Carp are all present in Upper Cormorant Lake. The presence of Zebra Mussels was first confirmed in the lake in 2019, therefore densities at the time of assessment were likely negligible and would not have had an effect on the fish community at that time. Direct competition with the native fish community by Curly-leaf Pondweed is unlikely. Any potential effects of Common Carp have not been evaluated or documented; however, recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data).

Historically, Upper Cormorant Lake had been stocked with Bluegill, Black Crappie, Largemouth Bass, Northern Pike, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 1.0 pound per littoral acre annually, as described in the 2014 lake management plan (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.

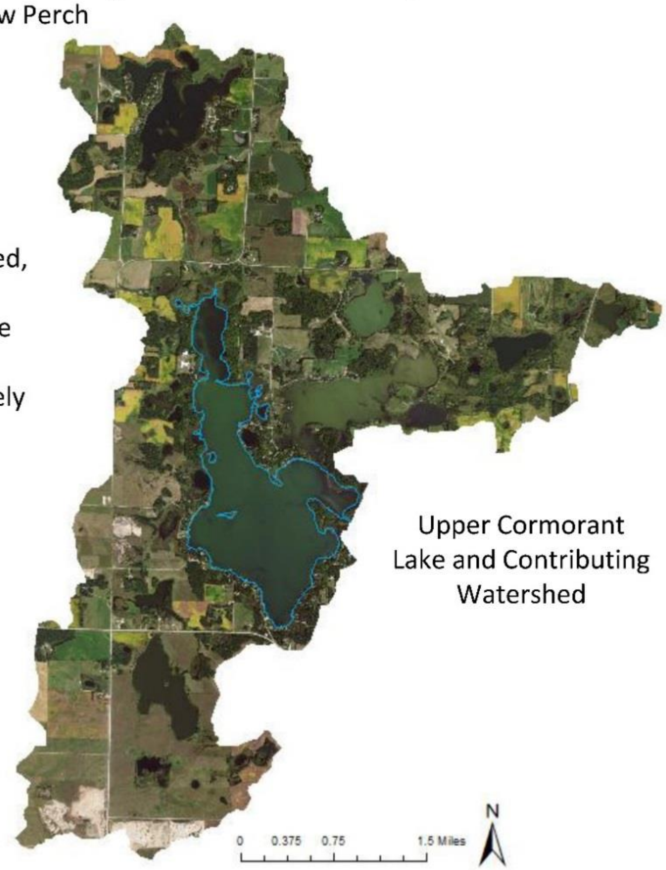
Relative abundance of adult Walleye in Upper Cormorant Lake has been relatively consistent and is currently slightly higher than the lake class inner quartile range; however, the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 Upper Cormorant 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 harvest, primarily of bullheads but including Common Carp, Bowfin, and Burbot, also occurred between 1950 and 2003, but this has likely had little effect on current fish community structure.

Figure 5. Upper Cormorant Lake (03-0588-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Upper Cormorant Lake (03-0588-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 42, 35, 27 (3, 10, 18 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Central Mudminnow, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Northern Pike, Pugnose Shiner, Pumpkinseed, Spottail Shiner, Tadpole Madtom, Walleye, Weed Shiner, Yellow Perch
  - Other species that have previously been sampled: Rock Bass
- **Candidate Causes:**
  - Eutrophication (excess nutrients): 33.3 ppb mean total phosphorus, 49% of contributing watershed classified as unnatural land cover
- **Inconclusive Causes:**
  - Physical habitat alteration: moderate dock density of 11.3 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 79, Curly-leaf Pondweed, Zebra Mussels, and Common Carp present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
  - Altered interspecific competition: Curly-leaf Pondweed, Zebra Mussels, and Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Use best management practices to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover



4.4. Middle Cormorant Lake (DOW 03-0602-00)

Middle Cormorant Lake is 366 acres in size and has a maximum depth of 40 feet. The littoral zone of the lake covers 39% of the lake area. Middle Cormorant Lake is scored with FIBI tool 4. Lakes scored with this tool are characterized as generally deep with simple (i.e., round) shorelines, less than 80% littoral area, and moderate species richness (Table 1).

Physical habitat alteration has been identified as a likely stressor to aquatic life use in Middle Cormorant Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition 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 Middle Cormorant Lake was sampled using seining and backpack electrofishing during August 2010 and July 2014 and gill netting and trap netting during August 2010 and 2014. The health of the fish community was evaluated using these data and FIBI tool 4. The FIBI scores of 29 and 35 were below the impairment threshold (38) developed for lakes that are similar to Middle Cormorant Lake (Table 3). The 2014 FIBI score was only a few points below the impairment threshold; therefore, Middle Cormorant Lake may be a good candidate to prioritize for restoration activities within the OTRW.

During the FIBI surveys, 27 fish species were captured (Table 7). The diversity and proportion of biomass from tolerant species (i.e., 19–32% Common Carp and Green Sunfish) exceeded levels expected for similar lakes as indicated by the respective FIBI metrics whereas the proportion of biomass from top carnivores (i.e., 45–52% Black Crappie, Largemouth Bass, Northern Pike, Rock Bass, and Walleye) in the gill nets was below the level expected for similar lakes. Seven intolerant species, four tolerant species, three small benthic dwelling species, and nine vegetative dwelling species were sampled. Species that were generally not sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 4 include Common Carp and Fathead Minnow (Table 7) that negatively affect several FIBI metric scores.

Because this is the first time utilizing the 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 game fish species has been sampled in Middle Cormorant Lake. Smallmouth Bass were sampled in two MNDNR Fisheries surveys in 1966 and 1977, but they have not been observed in MNDNR surveys since that time (MNDNR 2018c).

Data analysis/Evaluation for each candidate cause

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to an impaired fish community in Middle Cormorant Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 51, is low within Middle Cormorant Lake and well below the statewide average score of 73. A low score indicates that sites are typically developed and have a lower than expected amount of natural habitat. In this case, development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Middle Cormorant Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Middle Cormorant Lake. According to MPARS, at least 10 properties are, or have been, permitted to remove submersed plants via pesticide application or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. The 2016 lake management plan noted that many bulrush beds have been eliminated in areas of heavy shoreline development (MNDNR, unpublished data), although no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 156 docks (43.2 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

Curly-leaf Pondweed and Common Carp, two non-native species, are present in Middle Cormorant Lake. The lake was also designated as infested with Zebra Mussels in 2019 due to the species' presence in connected waters (i.e., Upper Cormorant and Nelson lakes). 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). No significant changes to the physical habitat resulting from the presence of Curly-leaf Pondweed have been documented.

The water level in Middle Cormorant Lake is unregulated (i.e., no water control structure) and has varied by 4.3 feet between 1971–2014 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., County Highway 1 and several field crossings) are present upstream of the inlet, which ultimately connects Middle Cormorant Lake to Nelson, Upper Cormorant, and Bijou lakes. Similarly, several crossings (i.e., Golden Lane, Swanies Creek Road, County Highway 5, South Big Cormorant Road, and several unnamed crossings) occur downstream of the outlet, which ultimately connects Middle Cormorant Lake to Big Cormorant Lake). One additional culvert further downstream at the connection with Pelican Lake (i.e., County Highway 9) has been identified as a potential barrier as cattails may be blocking passage (A. Hillman, MNDNR, unpublished data). These crossings should be investigated to determine their potential as barriers to fish passage. If these crossings are determined to act as barriers, actions should be considered to restore connectivity.

Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Middle Cormorant Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 16.5 ppb (N=30), chlorophyll-a is 3.9 ppb (N=30), and Secchi transparency is 14.0 feet (N=32) in Middle Cormorant Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 11,861 acres within the contributing watershed, 45.8% is classified as unnatural land cover (i.e., 41.0% agricultural, 4.5% developed, and 0.3% barren). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). In addition to relatively high land use disturbance in the contributing watershed, one upstream water body (i.e., Upper Cormorant Lake) contains relatively high nutrient levels (i.e., 33.3 ppb TP) and is also impaired for aquatic life use.

Approximately 54% of the agricultural land within Middle Cormorant's contributing watershed is hay and pasture land whereas 46% is cultivated. One feedlot is also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Middle Cormorant Lake and upstream water bodies such as Upper Cormorant Lake. In 1996, individual sewage treatment systems on 161 parcels surrounding the lake were inventoried and 38 were deemed non-compliant, but by 2004, all had been updated and were deemed compliant (BSWCD 2014). Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Middle Cormorant Lake, as indicated by a watershed-to-lake ratio of 31.8:1. The combination of a large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Although a high percentage of land is classified as unnatural, several AMAs and WPAs do exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Middle Cormorant Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Curly-leaf Pondweed and Common Carp are both present within Middle Cormorant Lake. Direct competition of Curly-leaf Pondweed with the fish community is unlikely. Common Carp catch rates from recent surveys would indicate that they are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data). Middle Cormorant Lake was also designated as infested with Zebra Mussels in 2019 due to the species' presence in connected waters (i.e. Upper Cormorant and Nelson lakes). At high densities, Zebra Mussels and Common Carp have the potential to directly compete with native species for resources.

Historically, Middle Cormorant Lake had been stocked with Northern Pike and Walleye. Prior to 2017, Walleye fry and fingerlings were stocked every third year at rates of 1,000 and 1.0 pounds per littoral acre, respectively, as described in the 2016 lake management plan (MNDNR, unpublished data). From 2017 to present, Walleye fingerlings have been stocked at a rate of 1.0 pound per littoral acre in even numbered years. 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.

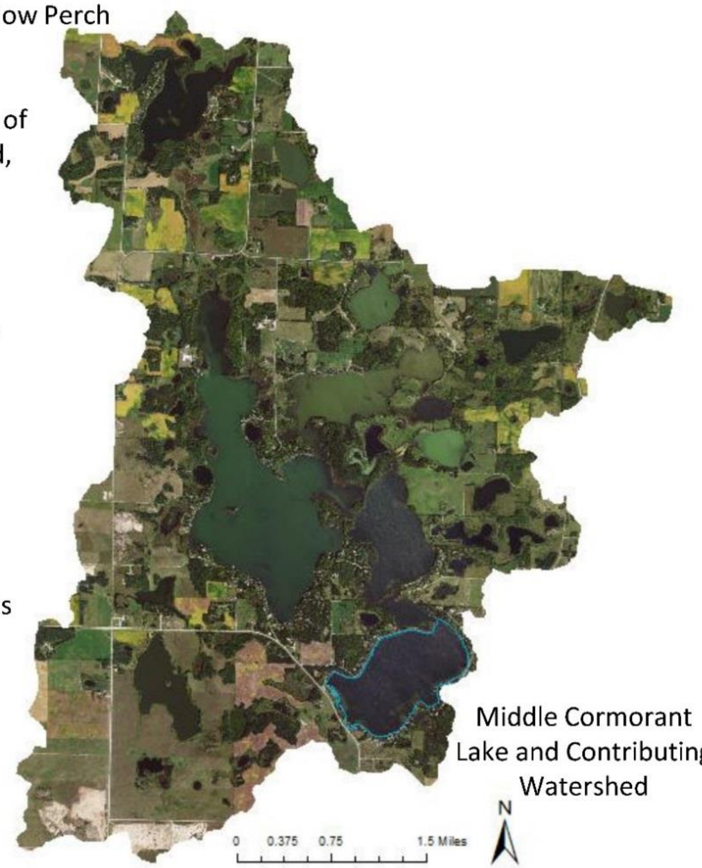
Relative abundance of adult Walleye in Middle Cormorant Lake has been relatively consistent and is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data).

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 Middle Cormorant 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 harvest of bullheads, Common Carp, and White Sucker also occurred between 1957 and 2000 and bait dealers currently harvest White Sucker eggs and have harvested Spottail Shiners historically. These activities have likely had little effect on current fish community structure.

Figure 6. Middle Cormorant Lake (03-0602-00) fish community and stressors; based on fish index of biological integrity (FIBI) results..

Middle Cormorant Lake (03-0602-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 29, 35 (9, 3 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Central Mudminnow, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Mimic Shiner, Northern Pike, Pugnose Shiner, Pumpkinseed, Rock Bass, Spottail Shiner, Tadpole Madtom, Walleye, Yellow Perch
  - Other species that have previously been sampled: Smallmouth Bass
- **Candidate Causes:**
  - Physical habitat alteration: very high dock density of 43.2 docks per mile of shoreline, low lakewide Score the Shore (StS) of 51, Curly-leaf Pondweed, Zebra Mussels, Common Carp present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 16.5 ppb mean total phosphorus, 46% of upstream watershed classified as unnatural land cover
  - Altered interspecific competition: Curly-leaf Pondweed, Zebra Mussels, Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation, evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - Address Upper Cormorant Lake aquatic life use impairment



4.5. Walker Lake (DOW 56-0310-00)

Walker Lake is 578 acres in size and has a maximum depth of 29 feet. The littoral zone of the lake covers 59% of the lake area. Walker Lake is scored with FIBI tool 4. Lakes scored with this tool are characterized as generally deep with simple (i.e., round) shorelines, less than 80% littoral area, and moderate species richness (Table 1).

Eutrophication, temperature regime changes, and decreased DO have been identified as likely stressors to aquatic life use in Walker Lake and will be evaluated further. Conversely, and physical habitat alteration and altered interspecific competition 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 Walker Lake was sampled using seining and backpack electrofishing during July 2013 and gill netting and trap netting during August 2014. The health of the fish community was evaluated using these data and FIBI tool 4. The FIBI score of 31 was below the impairment threshold (38) developed for lakes that are similar to Walker Lake (Table 3).

During the FIBI surveys, 26 fish species were captured (Table 7). The proportion of biomass from omnivores (i.e., 47% Black Bullhead, Brown Bullhead, Common Carp, White Sucker, and Yellow Bullhead) in the trap nets exceeded levels expected for similar lakes as indicated by the respective FIBI metrics. Eight intolerant species, two tolerant species, three small benthic dwelling species, and seven vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 4 include Green Sunfish and Tadpole Madtom (Table 7). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 three additional species have been sampled in Walker Lake. Burbot were sampled in one MNDNR Fisheries survey in 1998, Redhorse sp. were sampled in one MNDNR Fisheries survey in 1998, and Cisco were sampled in several MNDNR Fisheries surveys between 1971 and 2007, but they have not been observed in MNDNR surveys since that time (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 Walker Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 36.0 ppb (N=40), chlorophyll-a is 16.0 ppb (N=40), and Secchi transparency is 6.2 feet (N=63) in Walker Lake. These parameters indicate that the lake is likely receiving inputs of excess nutrients that could negatively affect the fish community. Of the 95,431 acres within the contributing watershed, 34.7% is classified as unnatural land cover (i.e., 31.1% agricultural and 3.6% developed). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 63% of the agricultural land within Walker Lake's contributing watershed is cultivated whereas 37% is hay and pasture land. Twenty-seven feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake.

Some residential development has occurred along the shoreline of Walker Lake. Although data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, a Sewer District was formed in 1981 as a means to ensure compliancy on lands within 1000 feet of the lake (BWR 2014). Runoff from lawns and discharge from failing individual sewage treatment systems could be contributing excess nutrients into the lake.

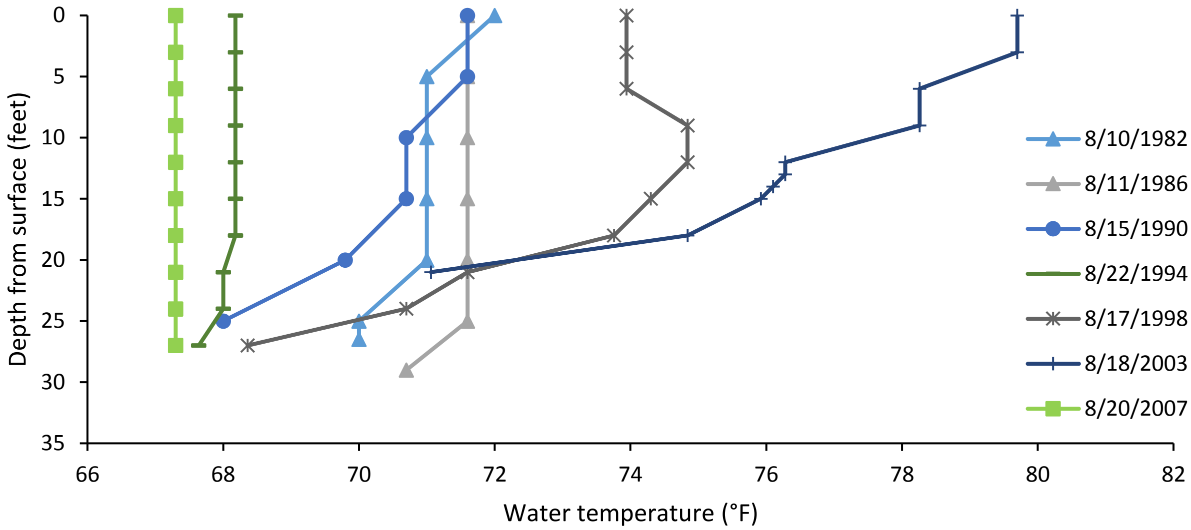
Additionally, the quantity of land within the contributing watershed was high relative to the size of Walker Lake, as indicated by a watershed-to-lake ratio of 165.0:1. The combination of a large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways.

Although a high percentage of land is classified as unnatural, several AMAs, WPAs, and WMAs do exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Temperature regime changes

Temperature regime changes are likely occurring at a level that would contribute to an impaired fish community in Walker Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 2.1 °F over the last century as a result of climate change, which is approximately 0.8 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1982 and 2007 to evaluate habitat for coldwater species (Figure 7). Two coldwater species (i.e., Cisco and Burbot) that would positively influence the FIBI score have historically been documented in Walker Lake. Their absence from recent surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures.

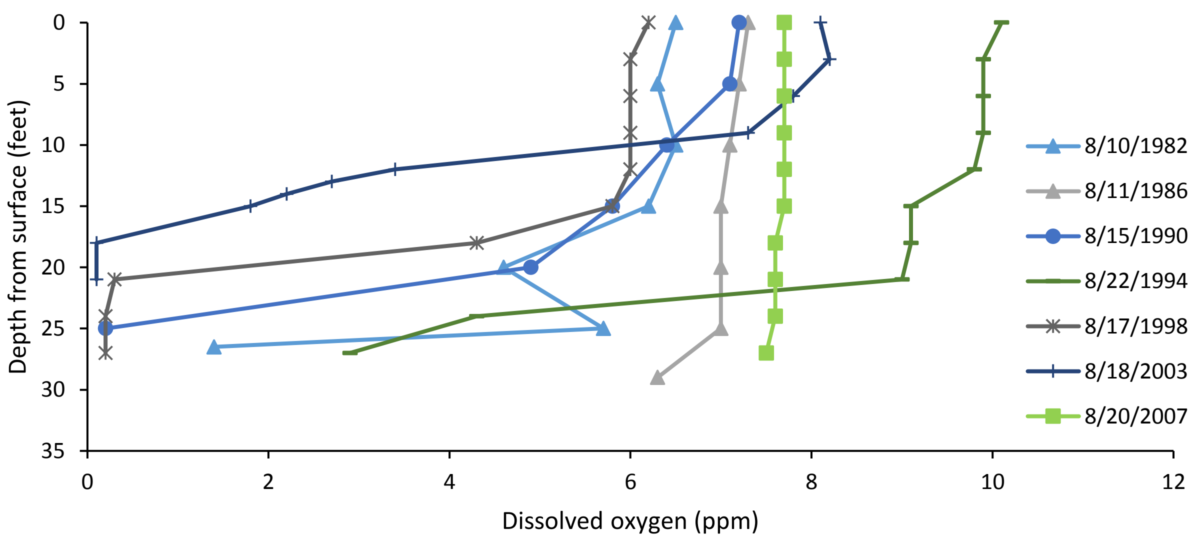
Figure 7. August water temperature (°F) by depth within Walker Lake (DOW 56-0310-00).



Decreased dissolved oxygen

Decreased DO is likely contributing to an impaired fish community in Walker Lake. A review of DO profile data collected concurrently with temperature profile data indicates that depths to approximately 12 to 22 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August in three of seven years (Figure 8). Water temperatures at these depths were warmer than the preferred range of coldwater species such as Burbot and Cisco and could be negatively affecting their ability to persist in Walker Lake. The low levels of oxygen at deeper depths are likely influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 8. August dissolved oxygen concentration (ppm) by depth within Walker Lake (DOW 56-0310-00).



Information about select inconclusive causes

Physical habitat alteration

Physical habitat alteration has the potential to occur at a level that would contribute to an impaired fish community in Walker Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 82, is moderate within Walker Lake and above the statewide average score of 73. Development has had the largest effect on the shoreline habitat component, which indicates that removal of trees, shrubs, and natural ground cover within that zone has most likely occurred. Removal of riparian vegetation may result in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. Several parcels totaling 85 acres are included in the Dead River-Walker Lake AMA that protect vulnerable shoreline on the northwest end of the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Walker Lake. According to MPARS, at least 22 properties are, or have been, permitted to remove submersed plants via pesticide application or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed on Walker Lake that documented 155 acres of floating-leaf and emergent vegetation. However, no historic or more recent surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 57 docks (11.9 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate and the relatively large area of floating-leaf and emergent vegetation.

Zebra Mussels and Common Carp, two non-native species, are present in Walker Lake. The presence of Zebra Mussels was first confirmed in the lake in 2018, therefore densities were likely negligible and would not have had an effect on the physical habitat in the lake at that time. Common Carp have also been sampled by MNDNR Fisheries surveys at low densities, per the lake management plan (MNDNR, unpublished data). However, at high densities, both species have the potential to directly compete with native fish for resources.

The water level in Walker Lake is unregulated (i.e., no water control structure) and has varied by 1.4 feet between 1963–2007 (MNDNR, unpublished data). Within the contributing watershed, one dam located at the outlet of Dead Lake, two bridges, and 16 culverts have been documented in the National Inventory of Dams, MDOT Bridge and Culvert Inventory, and the MNDNR Culvert Inventory, respectively. Other culverts and crossings also occur within the large contributing watershed, but they have not been evaluated. Of those culverts that have been documented and evaluated, 31% have been identified as potential barriers to fish passage. Those culverts within closest proximity to the lake should be investigated to determine their potential as barriers to fish passage. If these culverts are determined to act as barriers, actions should be considered to restore upstream connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Walker Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Two non-native species, Zebra Mussels and Common Carp, occur in Walker Lake and both have the potential to directly compete with the native fish community. The presence of Zebra Mussels was first confirmed in the lake in 2018, therefore densities at the time of assessment were likely negligible and would not have had an effect on the fish community at that time. Common Carp have also been sampled by MNDNR Fisheries surveys at low densities. However, at high densities, both species can directly compete with native fish for resources.

Historically, Walker Lake had been stocked with Northern Pike, Largemouth Bass, sunfish, and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 1,000 per littoral acre annually, as described in the 2014 lake management plan (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.

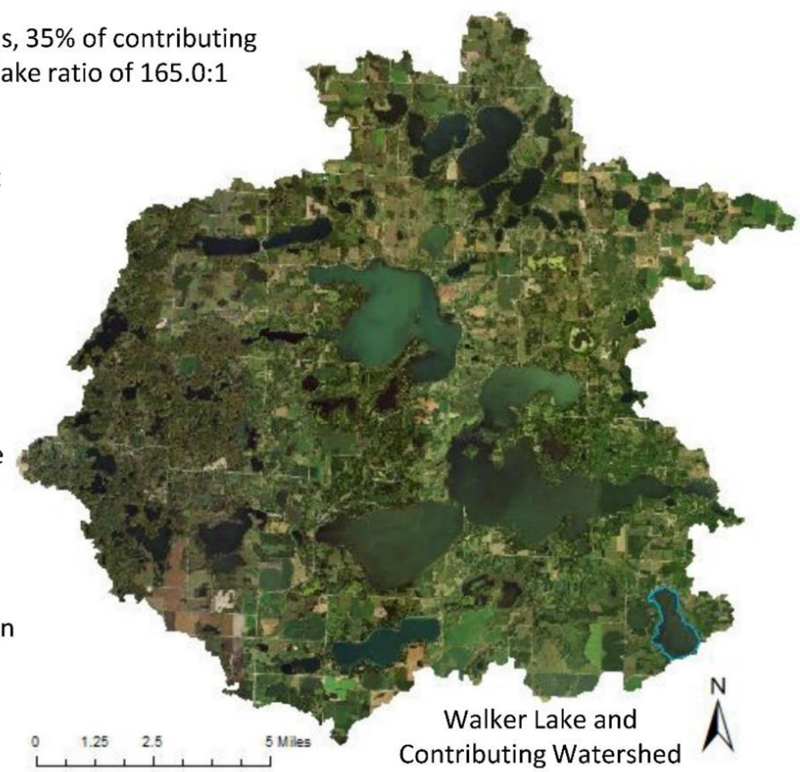
Relative abundance of adult Walleye in Walker Lake has been variable but is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 Walker 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. Some commercial harvest of bullheads also occurred in 2000 and 2001, but this has likely had little effect on current fish community structure.

Figure 9. Walker Lake (56-0310-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Walker Lake (56-0310-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 31 (7 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Bowfin, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Mimic Shiner, Northern Pike, Pumpkinseed, Rock Bass, Smallmouth Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Burbot, Cisco, redhorse sp.
- **Candidate Causes:**
  - Eutrophication (excess nutrients): 36.0 ppb mean total phosphorus, 35% of contributing watershed classified as unnatural land cover, large watershed-to-lake ratio of 165.0:1
  - Temperature regime changes: estimated 2.1 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: lack of adequate dissolved oxygen at depths containing suitable temperatures for coldwater species during summer months
- **Inconclusive Causes:**
  - Physical habitat alteration: moderate dock density of 11.9 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 82, Zebra Mussels and Common Carp present, some permitted aquatic plant removal activity, Dead Lake Dam and several crossings and culverts may act as potential barriers to fish passage
  - Altered interspecific competition: Zebra Mussels and Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Use best management practices to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



4.6. Little McDonald Lake (DOW 56-0328-00)

Little McDonald Lake is 1,312 acres in size and has a maximum depth of 109 feet. The littoral zone of the lake covers 31% of the lake area. Little McDonald Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration has been identified as a likely stressor to aquatic life use in Little McDonald Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition have been identified as inconclusive stressors and temperature regime changes and decreased DO have been eliminated as candidate stressors (Figure 12). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Little McDonald Lake was sampled using seining and backpack electrofishing during August 2016 and 2017, gill netting, and trap netting during August 2016. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI scores of 41 and 42 were below the impairment threshold (45) developed for lakes that are similar to Little McDonald Lake (Table 3). Both FIBI scores were only a few points below the impairment threshold; therefore, Little McDonald Lake may be a good candidate to prioritize for restoration activities within the OTRW.

During the FIBI surveys, 21 fish species were captured (Table 5). The diversity and proportion of small benthic dwelling species (i.e., <1-3% Iowa Darter and Johnny Darter) were below levels expected for similar lakes as indicated by the respective FIBI metrics. Six intolerant species, no tolerant species, two small benthic dwelling species, and six vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Black Bullhead, Bowfin, Cisco, Fathead Minnow, Golden Shiner, Logperch, and Tadpole Madtom (Table 5). Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 two additional species have been sampled in Little McDonald Lake. Shorthead Redhorse were sampled in one MNDNR Fisheries survey in 1988 and Cisco were sampled in one MNDNR Fisheries survey in 1959, but they have not been observed in MNDNR surveys since that time (MNDNR 2018c).

Data analysis/Evaluation for each candidate cause

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to an impaired fish community in Little McDonald Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 60, is low within Little McDonald Lake and below the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Little McDonald Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Little McDonald Lake. According to MPARS, at least one property is or has been permitted to remove submersed plants via pesticide application or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed on Little McDonald Lake that documented 28 acres of floating-leaf and emergent vegetation. However, no historic or more recent surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 165 docks (19.5 docks per mile of shoreline) were present on Little McDonald Lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the small, fragmented patches of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

Zebra Mussels and Chinese Mystery Snails, two non-native species, are present in Little McDonald Lake. No significant changes to the physical habitat resulting from the presence of Chinese Mystery Snails have been documented. The effects of Zebra Mussels have not been evaluated or documented.

The water level in Little McDonald Lake was unregulated (i.e., no water control structure) and had varied by 5.9 feet between 1992–2018 (MNDNR, unpublished data). Shoreline erosion, shoreland damage, and septic concerns during high water years resulted in the construction of an artificial outlet in 2018. The outlet removes excess water by pumping it from the east end of Little McDonald Lake and discharging it into the Otter Tail River. Aside from this artificial outlet, 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 Little McDonald Lake and therefore the FIBI score.

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Little McDonald Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 8.2 ppb (N=40), chlorophyll-a is 1.9 ppb (N=40), and Secchi transparency is 22.5 feet (N=41) in Little McDonald Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 8,410 acres within the contributing watershed, 50.9% is classified as unnatural land cover (i.e., 46.3% agricultural and 4.6% developed). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 75% of the agricultural land within Little McDonald's contributing watershed is cultivated whereas 25% is hay and pasture land. Five feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Little McDonald Lake and upstream water bodies such as Paul Lake. Although current data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had been completed in 1991 (Rufer and Sherman 2013). Therefore, parcels surrounding the lake should be prioritized for future inspections to ensure compliance is maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Little McDonald Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 6.4:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Undeveloped lands, particularly parcels in public ownership that are protected from future development, can 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. Several examples include AMAs and WMAs that are managed by the state, but neither occur within Little McDonald Lake's contributing watershed.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Little McDonald Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Zebra Mussels (2012) and Chinese Mystery Snails are both present in Little McDonald Lake. Direct competition with the native fish community by Chinese Mystery Snails is unlikely; however, the effects of Zebra Mussels have not been documented or evaluated.

Historically, Little McDonald Lake had been stocked with Northern Pike and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 2.0 pounds per littoral acre in odd years, as described in the 2016 lake management plan (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.

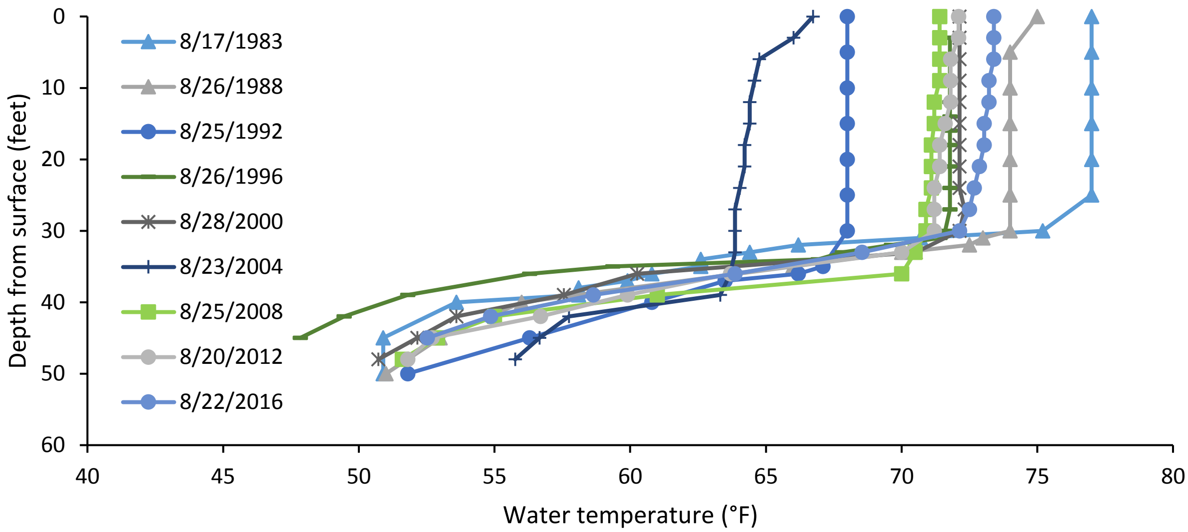
Relative abundance of adult Walleye in Little McDonald Lake has been somewhat variable but is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data).

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest were quantified during two creel surveys conducted in 1992 and 2008, although these surveys focused primarily on Walleye management (Fullhart and Wolters 2009). When compared to creel surveys for other similar lakes, angler effort was approximately average and Walleye harvest rates were below average. Special regulations were initiated in 1998 in an attempt to maintain quality size structure of Walleye. The creel survey results and special regulation may reflect some concern about angler harvest and its effect on fish community composition through altered interspecific competition. Some commercial harvest of bullheads also occurred between 2006 and 2008, but this has likely had little effect on current fish community structure.

Temperature regime changes

Temperature regime changes are not likely occurring at a level that would contribute to an impaired fish community in Little McDonald Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.9 °F over the last century as a result of climate change, which is approximately 0.6 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1983 and 2016 to evaluate habitat for coldwater species (Figure 10). One coldwater species (i.e., Cisco) that would positively influence the FIBI score has historically been documented in Little McDonald Lake. The absence of Cisco from recent surveys is not likely influenced by a temperature regime change as both temperature and oxygen concentrations below the thermocline are at suitable levels for the species. Given that only five individuals were sampled during one sampling event, it is unclear whether or not the species had ever become established within Little McDonald Lake.

Figure 10. August water temperature (°F) by depth within Little McDonald Lake (DOW 56-0328-00).



Decreased dissolved oxygen

Decreased DO is not likely contributing to an impaired fish community in Little McDonald Lake. A review of DO profile data indicates that depths to approximately 50 feet (i.e., the bottom of the profile) contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August when the lake was stratified (Figure 11). Water temperatures at these depths were within the preferred range of coldwater species such as Cisco and would not likely affect their ability to persist in Little McDonald Lake.

Figure 11. August dissolved oxygen concentration (ppm) by depth within Little McDonald Lake (DOW 56-0328-00).

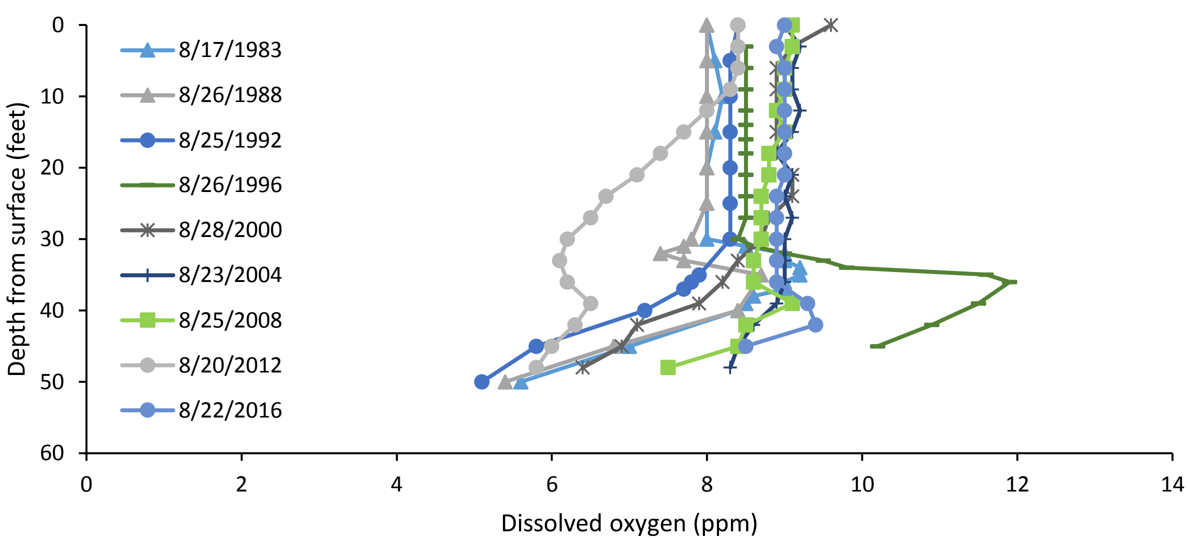
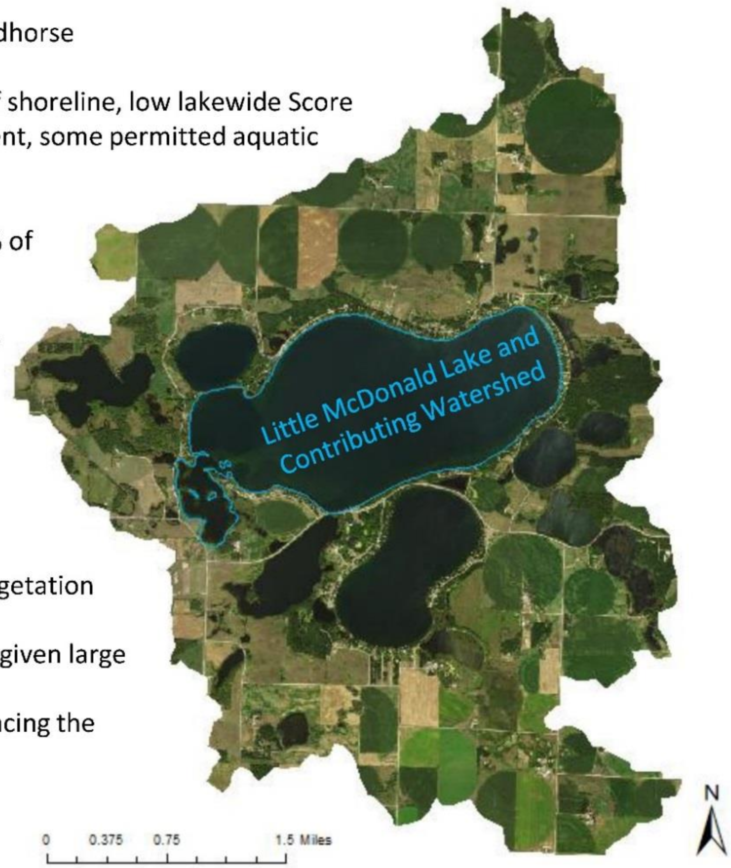


Figure 12. Little McDonald Lake (56-0328-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Little McDonald Lake (56-0328-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 41, 42 (4, 3 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Bluntnose Minnow, Brown Bullhead, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Bigmouth Shiner, Black Crappie, Blackchin Shiner, Bluegill, Central Mudminnnow, Hornyhead Chub, Iowa Darter, Johnny Darter, Largemouth Bass, Mimic Shiner, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Cisco, Shorthead Redhorse
- **Candidate Causes:**
  - Physical habitat alteration: high dock density of 19.5 docks per mile of shoreline, low lakewide Score the Shore (StS) of 60, Zebra Mussels and Chinese Mystery Snails present, some permitted aquatic plant removal activity, no significant inlets or outlets
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 8.2 ppb mean total phosphorus, 52% of contributing watershed classified as unnatural land cover
  - Altered interspecific competition: Zebra Mussels and Chinese Mystery Snails present, negative effects of stocking activities or harvest unlikely
- **Eliminated Causes:**
  - Temperature regime changes: estimated 1.9 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: adequate dissolved oxygen at depths containing suitable temperatures
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - The lack of connectivity, whether natural or unnatural, could be influencing the fish community



4.7. Paul Lake (DOW 56-0335-00)

Paul Lake is 347 acres in size and has a maximum depth of 81 feet. The littoral zone of the lake covers 31% of the lake area. Paul Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration has been identified as a likely stressor to aquatic life use in Paul Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition have been identified as an inconclusive stressors (Figure 13). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Paul Lake was sampled using seining, backpack electrofishing, gill netting, and trap netting during August 2015. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 32 was below the impairment threshold (45) developed for lakes that are similar to Paul Lake (Table 3).

During the FIBI survey, 15 fish species were captured (Table 5). The proportion of biomass from omnivores (i.e., 42% Brown and Yellow Bullheads) in the trap nets exceeded the level expected for similar lakes as indicated by the respective FIBI metric and the diversity of small benthic dwelling species (i.e., Johnny Darter) was below the level expected for similar lakes. Two intolerant species, one tolerant species, one small benthic dwelling species, and three vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Blackchin Shiner, Blacknose Shiner, Bowfin, Cisco, Fathead Minnow, Golden Shiner, Green Sunfish, Iowa Darter, Logperch, Rock Bass, Spottail Shiner, and Tadpole Madtom (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c).

Data analysis/Evaluation for each candidate cause

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to an impaired fish community in Paul Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 69, is moderate within Paul Lake and below the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that removal of trees, shrubs, and natural ground cover has most likely occurred. Removal of riparian vegetation may result in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Paul Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Paul Lake. According to MPARS, no properties on have recently been permitted to remove aquatic plants, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 65 docks (21.2 docks per mile of shoreline) were present on Paul Lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

Zebra Mussels and Chinese Mystery Snails, two non-native species, are present in Paul Lake. No significant changes to the physical habitat resulting from the presence of Chinese Mystery Snails have been documented. The effects of Zebra Mussels have not been documented or evaluated.

The water level in Paul Lake was unregulated (i.e., no water control structure) and had varied by 4.7 feet between 1994–2018 (MNDNR, unpublished data). Shoreline erosion, shoreland damage, and septic concerns during high water years resulted in the construction of an artificial outlet on connected Little McDonald Lake in 2018. The outlet removes excess water by pumping it from the east end of Little McDonald Lake and discharging it into the Otter Tail River. Aside from this artificial outlet, 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 Paul Lake and therefore the FIBI score.

Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Paul Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 12.7 ppb (N=39), chlorophyll-a is 3.4 ppb (N=39), and Secchi transparency is 20.5 feet (N=71) in Paul Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 2,446 acres within the contributing watershed, 67.7% is classified as unnatural land cover (i.e., 62.6% agricultural and 5.1% developed). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 79% of the agricultural land within Paul Lake's contributing watershed is cultivated, whereas 21% is hay and pasture land. Three feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Paul Lake and downstream water bodies such as Little McDonald Lake. Although current data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had been completed in 2006 (Rufer and Sherman 2013). Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into both Paul and Little McDonald lakes if not properly managed.

Paul Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 7.1:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Undeveloped lands, particularly parcels in public ownership that are protected from future development, can 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. Several examples include AMAs and WMAs that are managed by the state, but neither occur within Paul Lake's contributing watershed.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Paul Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Zebra Mussels (2012) and Chinese Mystery Snails are both present in Paul Lake. Direct competition with the native fish community by Chinese Mystery Snails is unlikely; however, the effects of Zebra Mussels have not been documented or evaluated.

Historically, Paul Lake had been stocked with Black Crappie, Largemouth Bass, Muskellunge, Northern Pike, sunfish, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 2.0 pounds per littoral acre in even years, as described in the 2015 lake management plan (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.

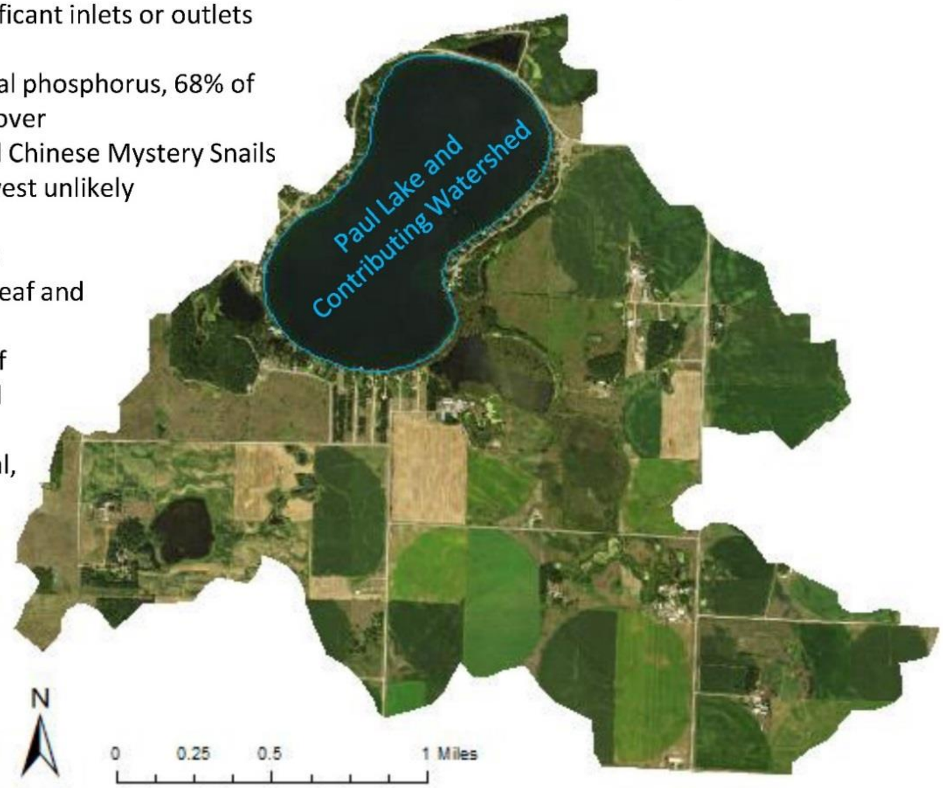
Relative abundance of adult Walleye in Paul Lake has been variable but is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities.

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 Paul 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. Some commercial harvest of bullheads and White Sucker also occurred in 1997 and 1998, but this has likely had little effect on current fish community structure.

Figure 13. Paul Lake (56-0335-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Paul Lake (56-0335-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 32 (13 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Bluegill, Johnny Darter, Largemouth Bass, Mimic Shiner, Northern Pike, Pumpkinseed, Walleye, Yellow Perch
- **Candidate Causes:**
  - Physical habitat alteration: high dock density of 21.2 docks per mile of shoreline, low lakewide Score the Shore (StS) of 69, Zebra Mussels and Chinese Mystery Snails present, no significant inlets or outlets
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 12.7 ppb mean total phosphorus, 68% of contributing watershed classified as unnatural land cover
  - Altered interspecific competition: Zebra Mussels and Chinese Mystery Snails present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - The lack of connectivity, whether natural or unnatural, could be influencing the fish community



4.8. Big McDonald Lake (DOW 56-0386-01)

Big McDonald Lake is 992 acres in size and has a maximum depth of 46 feet. The littoral zone of the lake covers 37% of the lake area. Big McDonald Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration, temperature regime changes, and decreased DO have been identified as likely stressors to aquatic life use in Big McDonald Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition have been identified as inconclusive stressors (Figure 16). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Big McDonald Lake was sampled using seining and backpack electrofishing during July 2013 and gill netting and trap netting during August 2013. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 30 was below the impairment threshold (45) developed for lakes that are similar to Big McDonald Lake (Table 3).

During the FIBI survey, 19 fish species were captured (Table 5). The diversity and proportion of small benthic dwelling species (i.e., <1% Johnny Darter) in the nearshore and the proportion of biomass from top carnivores (i.e., 41% Black Crappie, Largemouth Bass, Northern Pike, Rock Bass, and Walleye) were below the levels expected for similar lakes as indicated by the respective FIBI metrics. Four intolerant species, two tolerant species, one small benthic dwelling species, and four vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Black Bullhead, Blacknose Shiner, Bowfin, Cisco, Fathead Minnow, Golden Shiner, Iowa Darter, Logperch, Tadpole Madtom, and White Sucker (Table 5**Error! Reference source not found.**). Conversely, species such as Common Carp are generally not s ampled in similar lakes that contain healthy fish communities (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 two additional species have been sampled in Big McDonald Lake. Blacknose Shiner were sampled in a 1995 MNDNR Fisheries survey and Burbot were sampled in 1986 and 1990 MNDNR Fisheries surveys, but these species have not been observed in MNDNR surveys since that time (MNDNR 2018c). These historically sampled species may be 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

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to an impaired fish community in Big McDonald Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 70, is moderate within Big McDonald Lake and below the statewide average score of 73. Development has had a relatively uniform effect on the shoreland, shoreline, and aquatic habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Removal of riparian vegetation may result in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Big McDonald Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Big McDonald Lake. According to MPARS, at least 13 properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed the lake that documented 53 acres of floating-leaf and emergent vegetation. However, no historic or more recent surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 130 docks (22.3 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the relatively small, fragmented patches of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

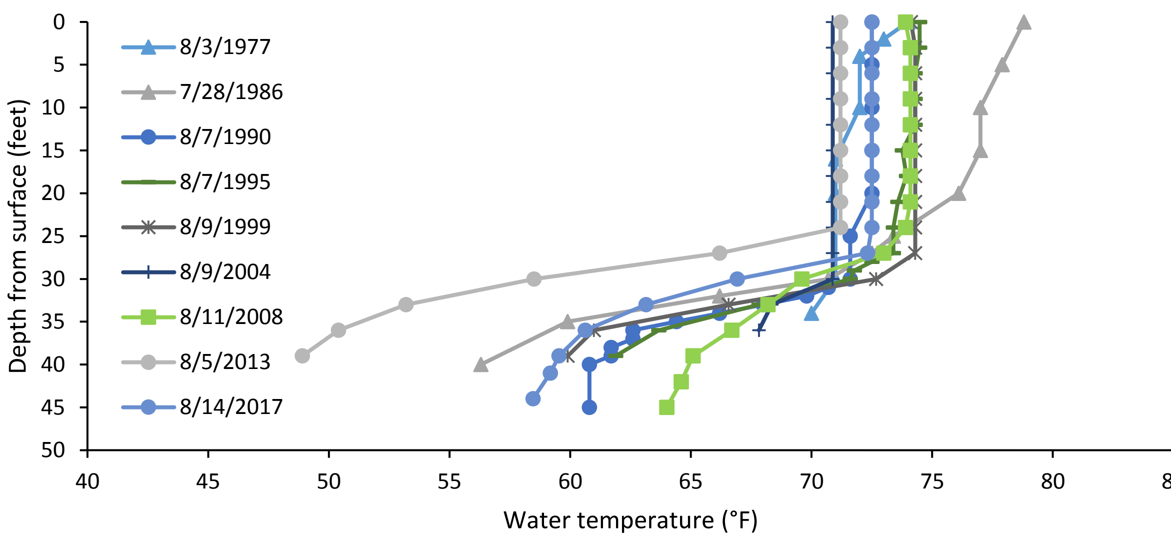
Common Carp, a non-native species, are present in Big McDonald Lake. Recent surveys indicate that they are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented.

The water level in Big McDonald Lake is unregulated (i.e., no water control structure) and has varied by 8.3 feet between 1935–2018 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., Engstrom Beach Road, several field crossings, and State Highway 108) are present downstream of the outlet. These crossings connect Big McDonald Lake to many lakes including Round and Star, and ultimately to the Otter Tail River. These crossings should be investigated to determine their potential as barriers to fish passage as at least one culvert just upstream of Round Lake has a negative slope, pooling issues, and a narrow width that could be limiting fish passage. If these crossings are determined to act as barriers, actions should be considered to restore upstream connectivity.

Temperature regime changes

Temperature regime changes are likely occurring at a level that would contribute to an impaired fish community in Big McDonald Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.9 °F over the last century as a result of climate change, which is approximately 0.6 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1977 and 2017 to evaluate habitat for coldwater species (Figure 14). One coldwater species (i.e., Burbot) that would positively influence the FIBI score has historically been documented in Big McDonald Lake. Their absence from recent surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures, or it could also be an artifact that Burbot are not frequently sampled with traditional gears.

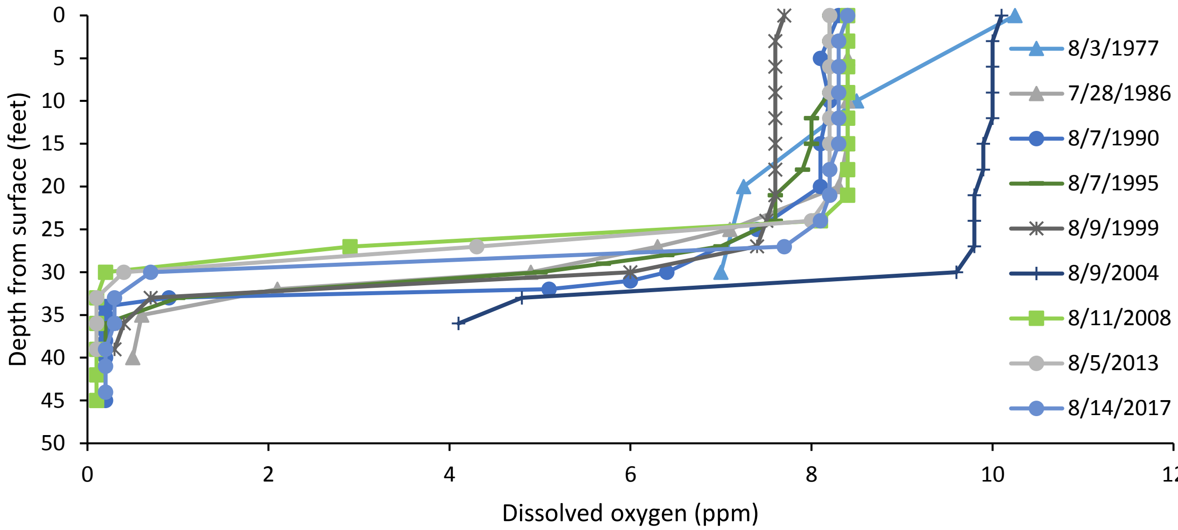
Figure 14. August water temperature (°F) by depth within Big McDonald Lake (DOW 56-0386-01.



Decreased dissolved oxygen

Decreased DO is likely contributing to an impaired fish community in Big McDonald Lake. A review of DO profile data indicates that depths to approximately 30 to 36 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August when the lake was stratified (Figure 15). Water temperatures at these depths were generally warmer than the preferred range of coldwater species such as Burbot and could be negatively affecting their ability to persist in Big McDonald Lake. The low levels of oxygen at deeper depths could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 15. August dissolved oxygen concentration (ppm) by depth within Big McDonald Lake (DOW 56-0386-01).



Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Big McDonald Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 15.0 ppb (N=38), chlorophyll-a is 4.4 ppb (N=38), and Secchi transparency is 14.8 feet (N=43) in Big McDonald Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 6,172 acres within the contributing watershed, 32.2% is classified as unnatural land cover (i.e., 27.9% agricultural and 4.3% developed). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 61% of the agricultural land within Big McDonald Lake's contributing watershed is cultivated whereas 39% is hay and pasture land. Two feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Big McDonald Lake. Although data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had been completed in 2010 (Rufer and Sherman 2013). Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Big McDonald Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 6.2:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

One AMA exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Big McDonald Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

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

Historically, Big McDonald Lake had been stocked with Northern Pike and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 1.0 pounds per littoral acre in even numbered years, as described in the 2017 lake management plan (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.

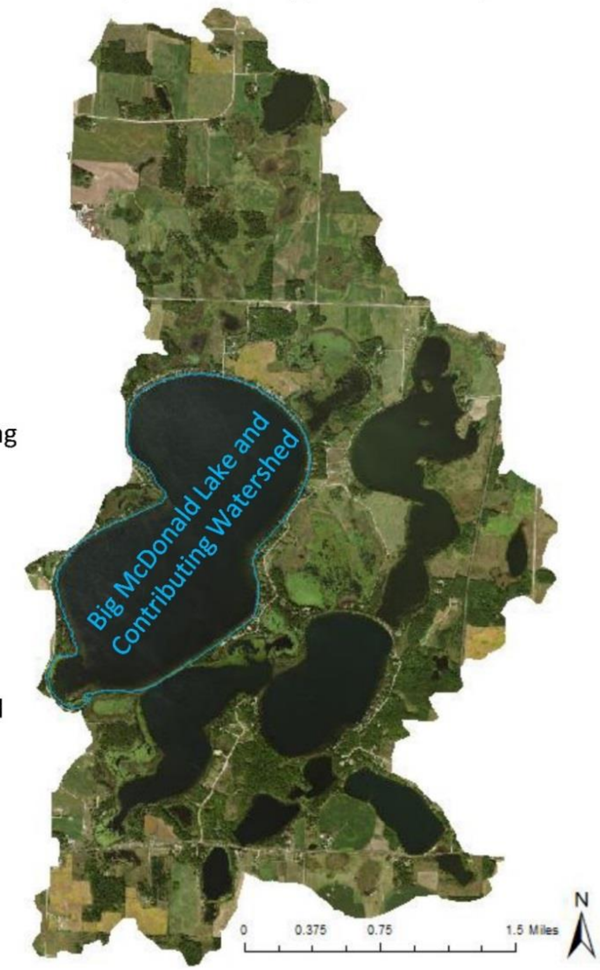
Relative abundance of adult Walleye in Big McDonald Lake has been variable and is currently slightly higher than the lake class inner quartile range; however, the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 Big McDonald 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. Some commercial harvest of bullheads also occurred in 2007 and 2008, but this has likely had little effect on current fish community structure.

Figure 16. Big McDonald Lake (56-0386-01) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Big McDonald Lake (56-0386-01) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 30 (15 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Bluntnose Minnow, Brown Bullhead, Common Carp, Green Sunfish, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Bigmouth Shiner, Black Crappie, Blackchin Shiner, Bluegill, Johnny Darter, Largemouth Bass, Mimic Shiner, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Blacknose Shiner, Burbot
- **Candidate Causes:**
  - Physical habitat alteration: high dock density of 22.3 docks per mile of shoreline, low lakewide Score the Shore (StS) of 70, some permitted aquatic plant removal activity, Common Carp present, no significant inlets or outlets
  - Temperature regime changes: estimated 1.9 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: lack of adequate dissolved oxygen at depths containing suitable temperatures during summer months
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 15.0 ppb mean total phosphorus, 32% of contributing watershed classified as unnatural land
  - Altered interspecific competition: Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover



4.9. Anna Lake (DOW 56-0448-00)

Anna Lake is 598 acres in size and has a maximum depth of 55 feet. The littoral zone of the lake covers 62% of the lake area. Anna Lake is scored with FIBI tool 4. Lakes scored with this tool are characterized as generally deep with simple (i.e., round) shorelines, less than 80% littoral area, and moderate species richness (Table 1).

Eutrophication, physical habitat alteration, and altered interspecific competition have been identified as inconclusive stressors to aquatic life use in Anna Lake and will be evaluated further (Figure 17). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Anna Lake was sampled using seining and backpack electrofishing during June 2009 and July 2014 and gill netting and trap netting during July 2009 and July 2014. The health of the fish community was evaluated using these data and FIBI tool 4. The FIBI scores of 12 and 15 were below the impairment threshold (38) developed for lakes that are similar to Anna Lake (Table 3).

During the FIBI survey, 16 fish species were captured (Table 7). The proportion of biomass from tolerant species (i.e., 6–22% Black Bullhead and Common Carp) in the trap nets exceeded the level expected for similar lakes as indicated by the respective FIBI metric and the relatively low proportion of biomass from top carnivores (i.e., 35–40% Black Crappie, Largemouth Bass, Northern Pike, and Walleye) in the gill nets was below the level expected for similar lakes. One intolerant species, two tolerant species, two small benthic dwelling species and two vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 4 include Banded Killifish, Blackchin Shiner, Blacknose Shiner, Golden Shiner, Pumpkinseed, Rock Bass, and Tadpole Madtom (Table 7). Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 7). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c).

Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Anna Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 13.9 ppb (N=12), chlorophyll-a is 3.8 ppb (N=12), and Secchi transparency is 10.1 feet (N=11) in Anna Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 10,221 acres within the contributing watershed, 62.9% is classified as unnatural land cover (i.e., 58.9% agricultural and 4.0% developed). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). The land use disturbance in the contributing watershed has likely contributed to the high nutrient levels (i.e., 152.6 ppb TP) and aquatic recreation use impairment on Norway Lake, which is upstream of Anna Lake. Although only weakly connected, future efforts to improve water quality in Norway Lake may also concurrently improve water quality in Anna Lake and other downstream water bodies.

Approximately 91% of the agricultural land within Anna Lake's contributing watershed is cultivated whereas 9% is hay and pasture land. Five feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Although the contributing watershed is predominantly rural and dominated by agricultural land, some residential development has occurred along the shoreline of Anna Lake. Individual sewage treatment systems on parcels surrounding the lake should be prioritized for future inspections to ensure compliance is met and maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Anna Lake, as indicated by a watershed-to-lake ratio of 17.1:1. The combination of a large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Although a high percentage of land is classified as unnatural, one WPA exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Physical habitat alteration

Physical habitat alteration has the potential to occur at a level that would contribute to an impaired fish community in Anna Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 84, is moderate within Anna Lake and above the statewide average score of 73. Development has had a relatively uniform but small effect on the shoreland, shoreline, and aquatic habitat components. Additional observation indicates that there is limited shoreline development and abundant bulrush and cattail stands present in the lake. Protection of this undisturbed riparian and aquatic habitat should continue to provide buffering capacity, shoreline stability, and future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Anna Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Anna Lake. According to MPARS, no properties on have recently been permitted to remove aquatic plants, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 32 docks (3.5 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). As such, the total amount of habitat loss from plant removal that has historically occurred and is presently occurring within the lake is likely low.

Common Carp and Purple Loosestrife, two non-native species, are present in Anna Lake. Common Carp have been sampled at variable densities in recent surveys, but average densities from other lakes in the same lake class are lacking for comparison (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented. The most recent lake management plan indicates that Purple Loosestrife was first observed in 1988 and was chemically treated in the early 1990's (MNDNR, unpublished data). The species is still present around the immediate area of the lake, but its effect on the physical habitat in the lake has not been evaluated or documented.

The water level in Anna Lake is unregulated (i.e., no water control structure) and has varied by 1.7 feet between 2001–2013 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., County Road 35, Pleasant Lake Road, 280th Avenue, County Road 1, Water Street Road, and an unnamed drive) are present downstream of the outlet, which has a weak connection to many lakes including Pleasant, Fish, and West Lost, and ultimately connects to the Otter Tail River. These crossings were not initially investigated, as they were not located on perennial streams; however, they could be investigated in the future to determine their potential as barriers to fish passage when there is flow. If these crossings are determined to act as significant barriers, actions could be considered to restore upstream connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to the impaired fish community in Anna Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Common Carp and Purple Loosestrife are present in Anna Lake. Direct competition of Purple Loosestrife with the fish community is unlikely; however, Common Carp have the potential displace other fish species if they occur at high densities.

Historically, Anna Lake had been stocked with Largemouth Bass, Northern Pike, sunfish, and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 1,000 per littoral acre in even years, as described in the 2014 lake management plan (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.

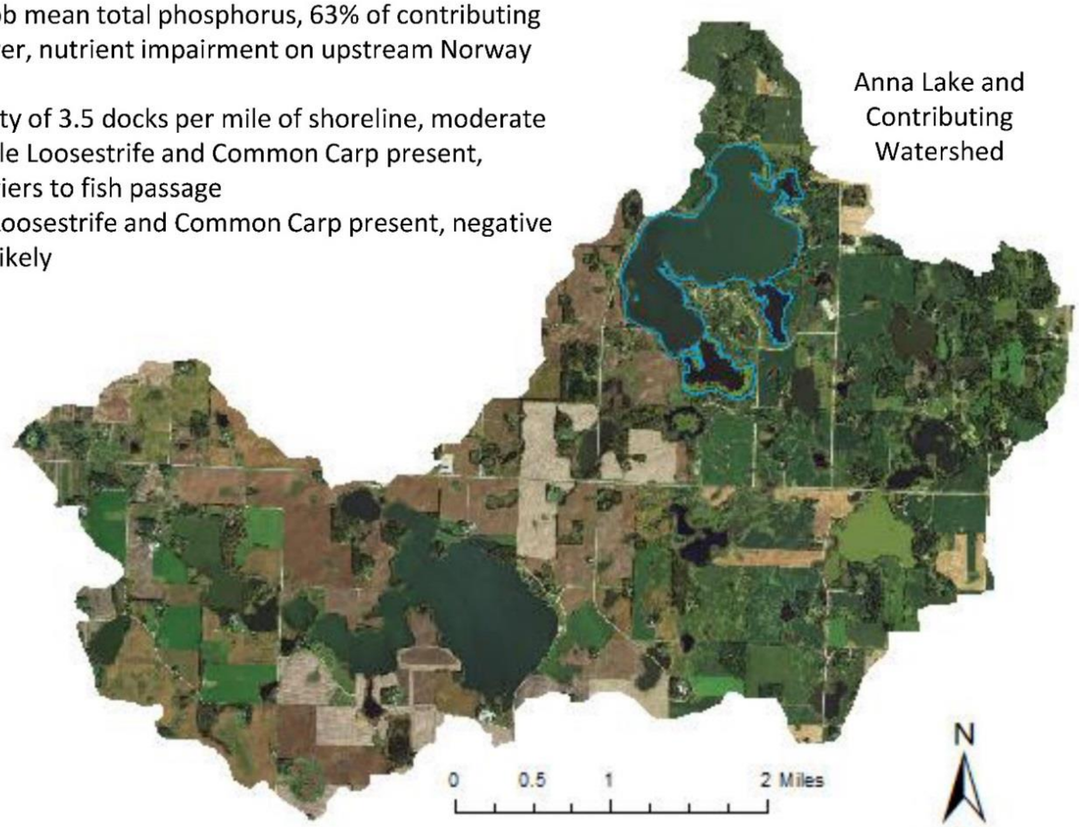
Relative abundances of adult Walleye and Yellow Perch in Anna Lake have been variable and both are currently higher than the lake class inner quartile range (MNDNR, unpublished data). The high relative abundance of Yellow Perch, a primary forage item for Walleye, would suggest that the fish community has not shifted towards being dominated by Walleye as a result of stocking.

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 Anna 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. Some commercial harvest of bullheads and Common Carp also occurred in 2009 and 2010, but this has likely had little effect on current fish community structure.

Figure 17. Anna Lake (56-0448-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Anna Lake (56-0448-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 12, 15 (26, 23 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Black Crappie, Bluegill, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Spottail Shiner, Walleye , Yellow Perch
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 13.9 ppb mean total phosphorus, 63% of contributing watershed classified as unnatural land cover, nutrient impairment on upstream Norway Lake
  - Physical habitat alteration: low dock density of 3.5 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 84, Purple Loosestrife and Common Carp present, several crossings may act as potential barriers to fish passage
  - Altered interspecific competition: Purple Loosestrife and Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - No candidate cause identified
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - Follow Norway Lake TMDL to minimize potential nutrient inputs from Norway Lake into Anna Lake
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



4.10. West Silent Lake (DOW 56-0519-00)

West Silent Lake is 347 acres in size and has a maximum depth of 58 feet. The littoral zone of the lake covers 34% of the lake area. West Silent Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration has been identified as an inconclusive stressor to aquatic life use in West Silent Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition have been eliminated as candidate stressors (Figure 18). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in West Silent Lake was sampled using seining and backpack electrofishing during August 2014 and June 2017 and gill netting and trap netting during June 2014. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI scores of 39 and 43 were below the impairment threshold (45) developed for lakes that are similar to West Silent Lake (Table 3). The 2017 FIBI score was only a few points below the impairment threshold; therefore, West Silent Lake may be a good candidate to prioritize for restoration activities within the OTRW.

During the FIBI survey, 21 fish species were captured (Table 5). The diversity of small benthic dwelling species (i.e., Iowa Darter and Johnny Darter) was below the level expected for similar lakes as indicated by the respective FIBI metric. Five intolerant species, one tolerant species, two small benthic dwelling species, and six vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Bowfin, Cisco, Fathead Minnow, Green Sunfish, Logperch, Mimic Shiner, and Tadpole Madtom (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c).

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication is not likely occurring at a level that would contribute to the impaired fish community in West Silent Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 10.6 ppb (N=40), chlorophyll-a is 2.5 ppb (N=40), and Secchi transparency is 18.1 feet (N=47) in West Silent Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Of the 1,743 acres within the contributing watershed, 24.5% is classified as unnatural land cover (i.e., 20.9% agricultural and 3.6% developed). The percentage of unnatural land cover is below a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 61% of agricultural land within West Silent Lake's contributing watershed is hay and pasture whereas 39% is cultivated. Two feedlots are also located within the contributing watershed (MPCA 2016). Although not identified as a stressor, surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake in the future if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of West Silent Lake. Although recent data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had last been completed in 2002 (Rufer and Sherman 2013). Therefore, parcels surrounding the lake should be prioritized for future inspections to ensure compliance and water quality are maintained. Although not identified as a stressor, runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake in the future if not properly managed.

Although eutrophication has been identified as an eliminated cause, West Silent Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 5.0:1. As such, management actions intended to reduce excess nutrient inputs into the lake would be relatively targeted and reasonably attainable.

Undeveloped lands, particularly parcels in public ownership that are protected from future development, can 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. Several examples include AMAs and WMAs that are managed by the state, but neither occur within West Silent Lake's contributing watershed.

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to an impaired fish community in West Silent Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 78, is moderate within West Silent Lake and above the statewide average score of 73. Development has had a relatively uniform effect on the shoreland, shoreline, and aquatic habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Removal of riparian vegetation may result in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on West Silent Lake to protect vulnerable shoreline from development.

Future residential development, particularly if it were to occur in the West Silent Lake's western bay, could result in the loss of important riparian vegetation, which serves as a buffer and source of future coarse woody habitat, and aquatic plants, which serve as important habitat for fish. Currently, emergent and submersed vegetation are most prevalent in the western bay, therefore efforts to protect these natural, minimally disturbed habitats should be prioritized.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within West Silent Lake. According to MPARS, at least three properties are, or have been, permitted to remove submersed and emergent plants via mechanical removal to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed on West Silent Lake that documented 8 acres of floating-leaf and emergent vegetation. However, no historic or more recent surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 77 docks (15.8 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the relatively isolated area of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

The water level in West Silent Lake has varied by 3.7 feet between 1967–2009 and is generally unregulated (MNDNR, unpublished data), although an outlet siphon was installed in the 1990s to mitigate high water events. Aside from this artificial outlet, 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 West Silent Lake and therefore the FIBI score.

Altered interspecific competition

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

No non-native species have been documented in West Silent Lake. Efforts to prevent introduction of non-native species should be prioritized.

Historically, West Silent Lake had been stocked with Northern Pike and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 1,000 per littoral acre in odd years, as described in the 2014 lake management plan (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.

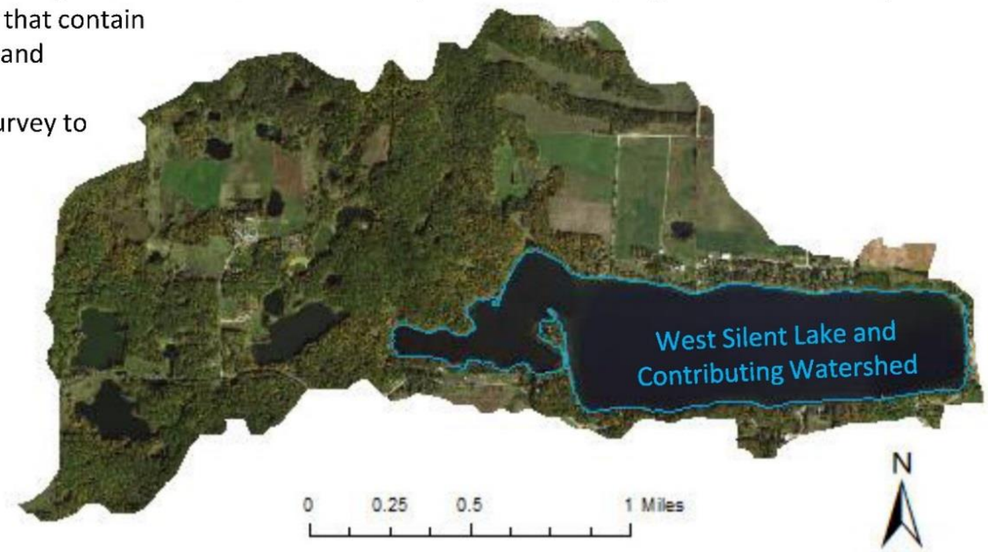
Relative abundance of adult Walleye in West Silent Lake has been variable and is currently below the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data). Likewise, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 West Silent 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.

Figure 18. West Silent Lake (56-0519-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

West Silent Lake (56-0519-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 43, 39 (2 and 6 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Central Mudminnow, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
- **Inconclusive Causes:**
  - Physical habitat alteration: moderate dock density of 15.8 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 78, some permitted aquatic plant removal activity, no significant inlets or outlets
- **Eliminated Causes:**
  - Eutrophication (excess nutrients): 10.6 ppb mean total phosphorus, 25% of contributing watershed classified as unnatural land cover
  - Altered interspecific competition: no non-native species present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - No candidate cause identified, the lack of connectivity, whether natural or unnatural, could be influencing the fish community
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Complete floating-leaf and emergent mapping survey to document existing stands



4.11. Fish Lake (DOW 56-0684-00)

Fish Lake is 1,078 acres in size and has a maximum depth of 19 feet. The littoral zone of the lake covers 82% of the lake area. Fish Lake is scored with FIBI tool 7. Lakes scored 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 use in Fish Lake and will be evaluated further. Conversely, physical habitat alteration and altered interspecific competition have been identified as inconclusive stressors (Figure 19). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Fish Lake was sampled using seining and backpack electrofishing during June 2015 and June 2017 and 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 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 scores of 31, 32, and 35 were below the impairment threshold (36) developed for lakes that are similar to Fish Lake (Table 3).

During the FIBI survey, 23 fish species were captured (Table 8). The proportion of biomass from tolerant species (i.e., 47–64% Black Bullhead and Common Carp) in the trap nets exceeded the level expected for similar lakes as indicated by the respective FIBI metric. Four tolerant species, three small benthic dwelling species, and five vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 7 include Blackchin Shiner, Blacknose Shiner, Central Mudminnow, Green Sunfish, Mimic Shiner, Smallmouth Bass, and Weed Shiner (Table 8). Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 8). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (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 Fish Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 32.0 ppb (N=12), chlorophyll-a is 12.0 ppb (N=12), and Secchi transparency is 4.4 feet (N=12) in Fish Lake. These parameters indicate that the lake is likely receiving inputs of excess nutrients that could negatively affect the fish community.

Of the 20,665 acres within the contributing watershed, 61.2% is classified as unnatural land cover (i.e., 57.1% agricultural and 4.1% developed). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 90% of the agricultural land within Fish Lake's contributing watershed is cultivated whereas 10% is hay and pasture land. Nine feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake.

Although the contributing watershed is predominantly rural and dominated by agricultural land, some residential development has occurred along the shoreline of Fish Lake. Data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake; however, these parcels could be prioritized for future inspections to ensure compliance is met and maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could be contributing excess nutrients into the lake.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Fish Lake, as indicated by a watershed-to-lake ratio of 19.2:1. 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, two WPAs exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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 occur at a level that would contribute to an impaired fish community in Fish Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 90, is high within Fish Lake and well above the statewide average score of 73. A high score indicates that a very high percentage of habitat is unaltered and that minimal vegetation removal has occurred. Additional observation indicates that there is limited shoreline development and large scattered stands of bulrush and cattail present in the lake. Protection of undisturbed riparian and aquatic habitat should provide buffering capacity, shoreline stability, and future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Fish Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Fish Lake. According to MPARS, at least three properties on Fish Lake are, or have been, permitted to remove submersed and emergent plants via mechanical removal to enhance recreational use or provide riparian access, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2016 Google imagery indicates that approximately 42 docks (4.3 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). As such, the total amount of habitat loss from plant removal that has historically occurred and is presently occurring within the lake is likely low.

Common Carp, a non-native species, are present in Fish Lake. Recent surveys indicate that they are sampled at a similar rate as other lakes in the same lake class (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented.

The water level in Fish Lake has varied by 12.7 feet between 1927–2007 and has increased since 1993 due to a change in elevation of the outlet culvert (MNDNR, unpublished data). Prior to this, the lake experienced periodic winterkill. No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., 280th Avenue, County Road 35, and Pleasant Lake Road) are present upstream of the inlet, which has a weak connection to Pleasant and Anna lakes. Similarly, several crossings (i.e., County Road 1, Water Street Road, and an unnamed drive) also occur downstream of the outlet, which has a weak connection to West Lost Lake and the Otter Tail River. These crossings should be investigated to determine their potential as barriers to fish passage. If these crossings are determined to act as barriers, actions should be considered to restore connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to occur at a level that would contribute to the impaired fish community in Fish Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Common Carp are present in Fish Lake. Common Carp have the potential to displace other native fish species if they occur at high densities; however, within Fish Lake, catch rates from recent 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, Fish Lake had been stocked with Yellow Perch and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 2,000 per littoral acre two of every three years, as described in the 2015 lake management plan (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.

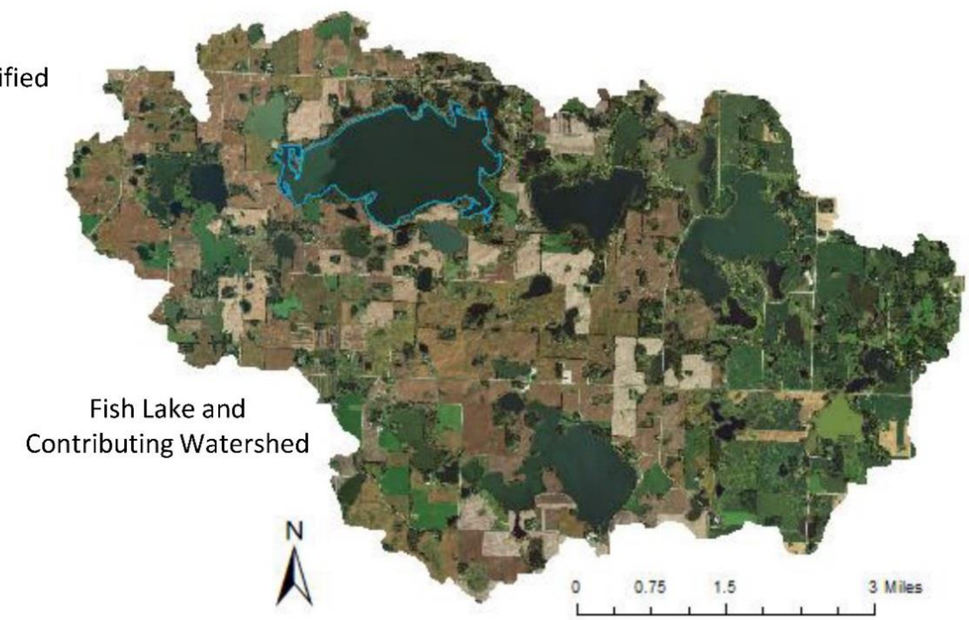
Relative abundance of adult Walleye in Fish Lake has been relatively consistent and is currently within the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data).

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 Fish 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.

Figure 19. Fish Lake (56-0684-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Fish Lake (56-0684-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 35, 32, 31 (1, 4, 5 points below impairment threshold)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Common Carp, Fathead Minnow, Green Sunfish
  - Species sampled that are neutral to the FIBI score: Bluntnose Minnow, Brown Bullhead, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Bluegill, Bowfin, Brook Stickleback, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Tadpole Madtom, Walleye, Yellow Perch
- **Candidate Causes:**
  - Eutrophication (excess nutrients): 32.0 ppb mean total phosphorus, 61% of contributing watershed classified as unnatural land cover, individual sewage treatment system compliance information unavailable
- **Inconclusive Causes:**
  - Physical habitat alteration: low dock density of 4.3 docks per mile of shoreline, high lakewide Score the Shore (StS) of 90, Common Carp present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
  - Altered interspecific competition: Common Carp present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Use best management practices to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



4.12. Jewett Lake (DOW 56-0877-00)

Jewett Lake is 731 acres in size and has a maximum depth of 75 feet. The littoral zone of the lake covers 36% of the lake area. Jewett Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration has been identified as a likely stressor to aquatic life use in Jewett Lake and will be evaluated further. Conversely, eutrophication, temperature regime changes, and decreased DO have been identified as inconclusive stressors and altered interspecific competition has been eliminated as a candidate stressor (Figure 22). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Jewett Lake was sampled using seining and backpack electrofishing during August 2011 and June 2014 and gill netting and trap netting during August 2011 and August 2014. The health of the fish community was evaluated using these data and FIBI tool 2. The two FIBI scores of 43 were below the impairment threshold (45) developed for lakes that are similar to Jewett Lake (Table 3). Both FIBI scores were only a couple points below the impairment threshold; therefore, Jewett Lake may be a good candidate to prioritize for restoration activities within the OTRW.

During the FIBI surveys, 23 fish species were captured (Table 5). The proportion of biomass from insectivores (i.e., 10–20% Bluegill, Hybrid Sunfish, and Yellow Perch) in the trap nets and proportion of biomass from top carnivores (e.g., 44–51% Black Crappie, Channel Catfish, Largemouth Bass, Northern Pike, and Walleye) in the gill nets were below the levels expected for similar lakes as indicated by the respective FIBI metric. Five intolerant species, one tolerant species, three small benthic dwelling species, and four vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Black Bullhead, Blackchin Shiner, Bowfin, Logperch, Mimic Shiner, and Tadpole Madtom (Table 5). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c).

Data analysis/Evaluation for each candidate cause

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to an impaired fish community in Jewett Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 52, is low within Jewett Lake and well below the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. Historically, dense stands of bulrush and cattail bogs occurred around the perimeter of the lake; however, extensive development along the north and east shorelines has essentially reduced these stands to areas adjacent to two parcels totaling 13 acres that are currently owned and protected by the State of Minnesota as part of Jewett Lake AMA. To protect some of the important aquatic vegetation associated with these sites, the area along the southwest shoreline is posted annually as a Largemouth Bass spawning area. No fishing or boating is allowed in this area from ice-out to June 30, inclusive.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Jewett Lake. According to MPARS, at least 17 properties are, or have been, permitted to remove submersed and emergent plants via pesticide application, mechanical removal, or automated aquatic plant control devices to provide riparian access, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed on the lake that documented 34 acres of floating-leaf and emergent vegetation. However, no historic or more recent surveys have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 151 docks (37.1 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the relatively isolated and fragmented areas of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

The water level in Jewett Lake has varied by 4.0 feet between 1989–2018 and is generally unregulated (MNDNR, unpublished data), although pipe was installed in 1999 to drain water from Jewett Lake into Long Lake and the Pelican River. Aside from this artificial outlet, 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 Jewett Lake and therefore the FIBI score.

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to the impaired fish community in Jewett Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 19.9 ppb (N=40), chlorophyll-a is 5.4 ppb (N=40), and Secchi transparency is 13.8 feet (N=36) in Jewett Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 1,789 acres within the contributing watershed, 42.2% is classified as unnatural land cover (i.e., 36.2% agricultural and 6.0% developed). The percentage of unnatural land cover currently exceeds a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 80% of the agricultural land within Jewett Lake's contributing watershed is cultivated whereas 20% is hay and pasture land. No feedlots are located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Jewett Lake. Although data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had last been completed in 2001 (Rufer and Sherman 2013). Therefore, parcels surrounding the lake should be prioritized for future inspections to ensure compliance is maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Jewett Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 2.4:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Although a high percentage of land is classified as unnatural, one AMA exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Altered interspecific competition

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

No non-native species have been documented in Jewett Lake. Efforts to prevent introduction of non-native species should be prioritized.

Historically, Jewett Lake had been stocked with Black Crappie, Bluegill, Northern Pike, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 2.0 pounds per littoral acre in even years, as described in the 2014 lake management plan (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.

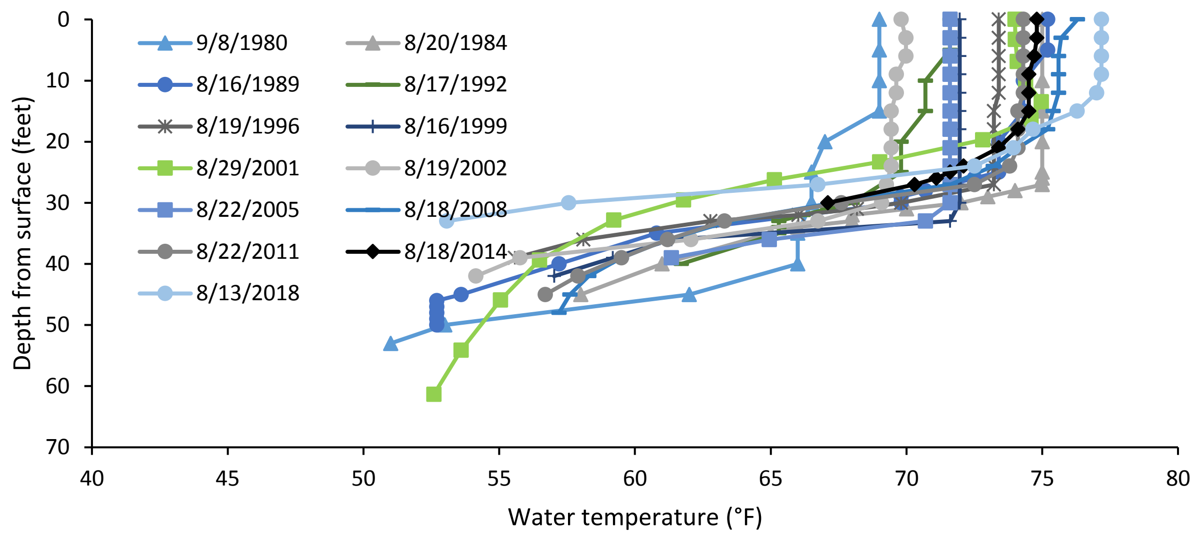
Relative abundance of adult Walleye in Jewett Lake has been somewhat variable and is currently slightly higher than the lake class inner quartile range; however, the fish community has not shifted towards being dominated by Walleye as a result of stocking. Furthermore, Yellow Perch (a primary forage species for Walleye) have also been sampled at variable densities in recent surveys (MNDNR, unpublished data).

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest were quantified during one creel survey conducted during 1986–1987 (Kavanaugh and Fierstine 1987); however, no recent creel surveys have been conducted to compare with the 1986–1987 results. Results during the survey indicated that fishing pressure as measured in angler hours per acre was average when compared with other small Otter Tail County lakes but higher than larger Otter Tail County lakes. Regardless, no special regulations are currently implemented that might reflect concerns about angler harvest or result in changes to fish community composition through altered interspecific competition. Cisco sport netting also remains open seasonally on Jewett Lake.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to an impaired fish community in Jewett Lake; however, this has been identified as an inconclusive stressor because the coldwater species that would be most strongly affected by this stressor were sampled during the FIBI surveys. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.2 °F over the last century as a result of climate change, which is approximately 0.1 °F cooler than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR and MPCA sampling between 1980 and 2018 to evaluate habitat for coldwater species (Figure 20). One coldwater species (i.e., Cisco) that positively influences the FIBI score is frequently sampled at varying levels in Jewett Lake. Despite this, temperature and oxygen conditions in the lake may not be favorable for the species in the future if summer water temperatures increase or DO concentrations at suitable temperatures decrease.

Figure 20. August water temperature (°F) by depth within Jewett Lake (DOW 56-0877-00).



Decreased dissolved oxygen

Decreased DO has the potential to be contributing to an impaired fish community in Jewett Lake; however, it has been identified as an inconclusive stressor. A review of DO profile data indicates that depths to approximately 24 to 33 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August when the lake was stratified (Figure 21). Water temperatures at these depths were generally within the preferred range of coldwater species such as Cisco, although the amount of preferred habitat was generally limited to only a few feet of the water column. Future increases in summer water temperature or inputs of excess nutrients, subsequent decomposition of the resulting organic matter, and reduced DO concentrations have the potential to negatively affect the species' ability to persist in Jewett Lake.

Figure 21. August dissolved oxygen concentration (ppm) by depth within Jewett Lake (DOW 56-0877-00).

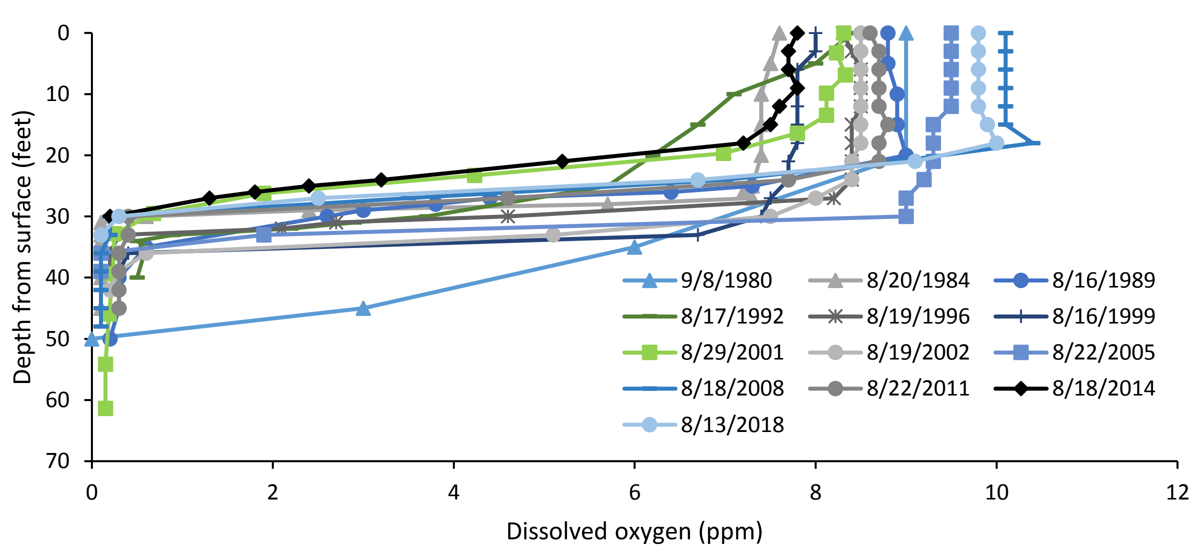
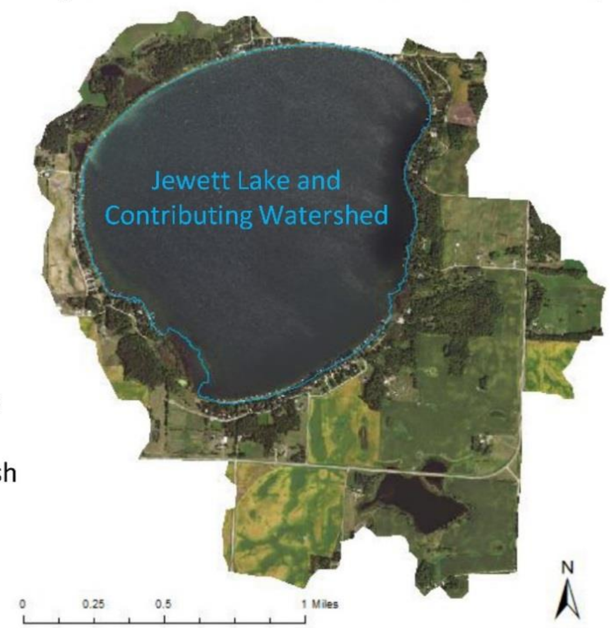


Figure 22. Jewett Lake (56-0877-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Jewett Lake (56-0877-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 43, 43 (2, 2 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Bluntnose Minnow, Brown Bullhead, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blacknose Dace, Blacknose Shiner, Bluegill, Channel Catfish, Cisco, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
- **Candidate Causes:**
  - Physical habitat alteration: very high dock density of 37.1 docks per mile of shoreline, low lakewide Score the Shore (StS) of 52, some permitted aquatic plant removal activity, no significant inlets or outlets
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 19.9 ppb mean total phosphorus, 42% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 2.4:1
  - Temperature regime changes: estimated 1.2 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: adequate dissolved oxygen at limited depths containing suitable temperatures during summer months
- **Eliminated Causes:**
  - Altered interspecific competition: no non-native species present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - The lack of connectivity, whether natural or unnatural, could be influencing the fish community



5. Evaluation of candidate causes in vulnerable lakes

Seven lakes assessed as either fully supporting or insufficient information were considered to be vulnerable to future impairment. These lakes include Toad (03-0107-00), Little Toad (03-0189-00), Acorn (03-0258-00), Cotton (03-0286-00), Sallie (03-0359-00), Big Cormorant (03-0576-00), and Star (03-0385-00). Causes of stress to the fish communities in these vulnerable lakes are evaluated.

5.1. Toad Lake (DOW 03-0107-00)

Toad Lake is 1,716 acres in size and has a maximum depth of 29 feet. The littoral zone of the lake covers 33% of the lake area. Toad Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration, altered interspecific competition, and temperature regime changes have been identified as inconclusive stressors to aquatic life use in Toad Lake and will be evaluated further. Conversely, eutrophication and decreased DO have been eliminated as candidate stressors (Figure 24). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Toad Lake was sampled using seining and backpack electrofishing during August 2016 and June 2017 and gill netting and trap netting during August 2016. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 42 was below the impairment threshold (45) developed for lakes that are similar to Toad Lake whereas the FIBI score of 45 was equal to the impairment threshold (Table 3).

During the FIBI surveys, 28 fish species were captured (Table 6). The proportion of small benthic dwelling species (i.e., <1% Iowa, Johnny, and Least darters) in the nearshore was below the level expected for similar lakes as indicated by the respective FIBI metric. Seven intolerant species, two tolerant species, three small benthic dwelling species, and ten vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Fathead Minnow, Green Sunfish, Logperch, and Tadpole Madtom (Table 6). Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 6). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 has been sampled in Toad Lake. Burbot were sampled in five MNDNR Fisheries surveys between 1959–2001, but they have not been observed in MNDNR surveys since that time (MNDNR 2018c).

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication is not likely occurring at a level that would contribute to a vulnerable fish community in Toad Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 26.3 ppb (N=36), chlorophyll-a is 12.4 ppb (N=36), and Secchi transparency is 9.8 feet (N=192) in Toad Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Of the 9,096 acres within the contributing watershed, 14.6% is classified as unnatural land cover (i.e., 10.9% agricultural, 3.4% developed, and 0.3% barren).The percentage of unnatural land cover is below a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 56% of the agricultural land within Toad Lake's contributing watershed is hay and pasture land whereas 44% is cultivated. Three feedlots are also located within the contributing watershed (MPCA 2016). Although not identified as a stressor, surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake in the future if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Toad Lake. In 1995, individual sewage treatment systems on 186 parcels surrounding the lake were inventoried and 48 were deemed non-compliant, but by 2004, all had been updated and were deemed compliant (BSWCD 2014). Future inspections for compliance are also planned for summer 2020 to ensure compliance is maintained (K. Vareberg, Becker County Zoning, personal communication). Although not identified as a stressor, runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake in the future if not properly managed.

Although eutrophication has been identified as an eliminated cause, Toad Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 5.3:1. As such, management actions intended to reduce excess nutrient inputs into the lake would be relatively targeted and reasonably attainable.

One AMA and several parcels of state forest exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to a vulnerable fish community in Toad Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 75, is moderate within Toad Lake and above the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. Several parcels totaling 115 acres are included in the Toad Lake AMA that protect vulnerable shoreline on the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Toad Lake. According to MPARS, at least eight properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 136 docks (13.4 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate.

Curly-leaf Pondweed and Common Carp, two non-native species, are present in Toad Lake. Curly-leaf Pondweed has been present since at least 1959 and occurs at a low frequency (Perleberg 2006). Long-term Curly-leaf Pondweed management activities have included mechanical harvest and chemical treatment. Recent surveys indicate that Common Carp are sampled at a similar rate as other lakes in the same lake class (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented.

The water level in Toad Lake has varied by 5.7 feet between 1938–2019 and is regulated by a Works Progress Administration dam constructed in 1937 (MNDNR, unpublished data). The dam is 15 feet wide, was authorized to have 1.0 feet of stop logs in place, and includes a fish barrier to prevent Common Carp from entering the lake. Several culverts downstream of Toad Lake that ultimately connect Toad Lake to the Toad River, Big Pine Lake, and the Otter Tail River have also been identified as potential barriers to fish passage due to high water velocity or constricted size (A. Hillman, MNDNR, unpublished data). MPCA has also identified that the Toad River downstream of Little Toad Lake is impaired for aquatic life use and has identified several stressors to this reach including loss of longitudinal connectivity, insufficient physical habitat, and high suspended sediment (MPCA 2019). Potential effects to aquatic life within the lake are uncertain; however, future investigation may be warranted to restore and/or maintain connectivity to the downstream watershed. If the dam and other crossings are determined to act as barriers, actions should be considered to restore connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Toad Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities.

Curly-leaf Pondweed and Common Carp are both present in Toad Lake. Direct competition of Curly-leaf Pondweed with the fish community is unlikely; however, Common Carp have the potential displace other fish species if they occur at high densities. Catch rates from recent surveys would indicate that Common Carp are occurring at relatively normal densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Toad Lake had been stocked with Bluegill, Black Crappie, Largemouth Bass, Northern Pike, White Sucker, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 1.0 pounds per littoral acre in odd years, as described in the 2018 lake management plan (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.

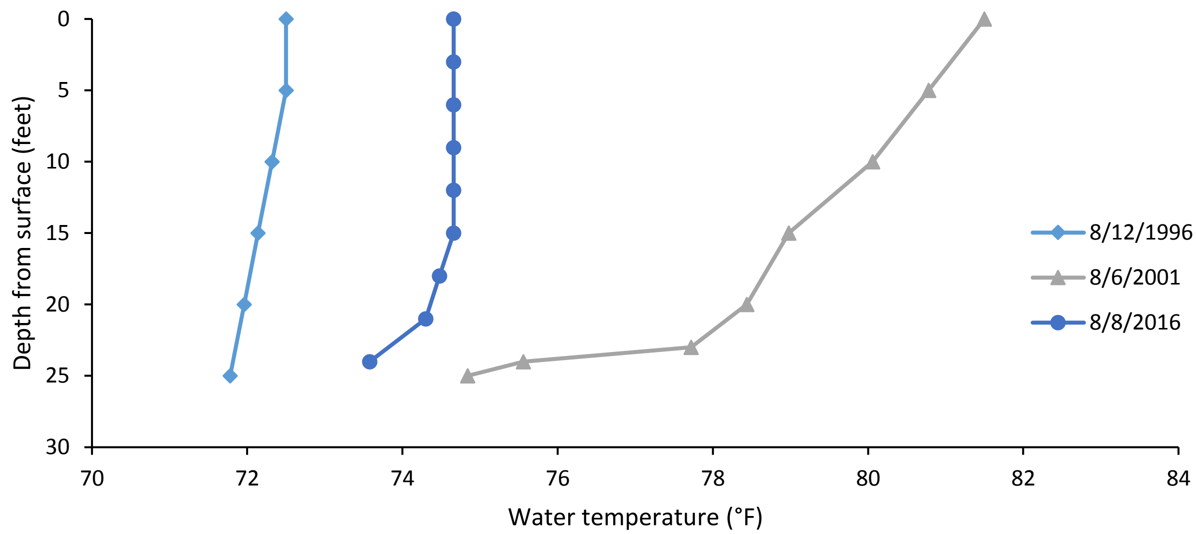
Relative abundance of adult Walleye in Toad Lake has been somewhat variable and is currently slightly higher than the lake class inner quartile range; however, the fish community has not shifted towards being dominated by Walleye as a result of stocking. Conversely, Yellow Perch (a primary forage species for Walleye) have exhibited a declining trend in recent surveys, but the observed decline is consistent with the statewide trend (Bethke et al. 2015) and may not be a direct result of current Walleye densities that have been influenced by stocking.

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 Toad 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 harvest, primarily of bullheads but including Burbot, Bowfin, Common Carp, Freshwater Drum, White Sucker, and Yellow Perch, also occurred between 1946 and 2004, but this has likely had little effect on current fish community structure.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to a vulnerable fish community in Toad Lake; however, this has been identified as an inconclusive stressor based on the lake’s morphology, which may naturally limit the ability of coldwater species to persist in the lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.8 °F over the last century as a result of climate change, which is approximately 0.5 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1996 and 2016 to evaluate habitat for coldwater species (Figure 23). One coldwater species (i.e., Burbot) that would positively influence the FIBI score has historically been documented in Toad Lake. Absence of this species from recent surveys could be influenced by temperature regime changes, particularly in lakes such as Toad Lake that do not stratify, or only weakly stratify, due to their large size relative to their shallow depth, or it could also be an artifact that Burbot are not frequently sampled with traditional gears.

Figure 23. August water temperature (°F) by depth within Toad Lake (DOW 03-0107-00).



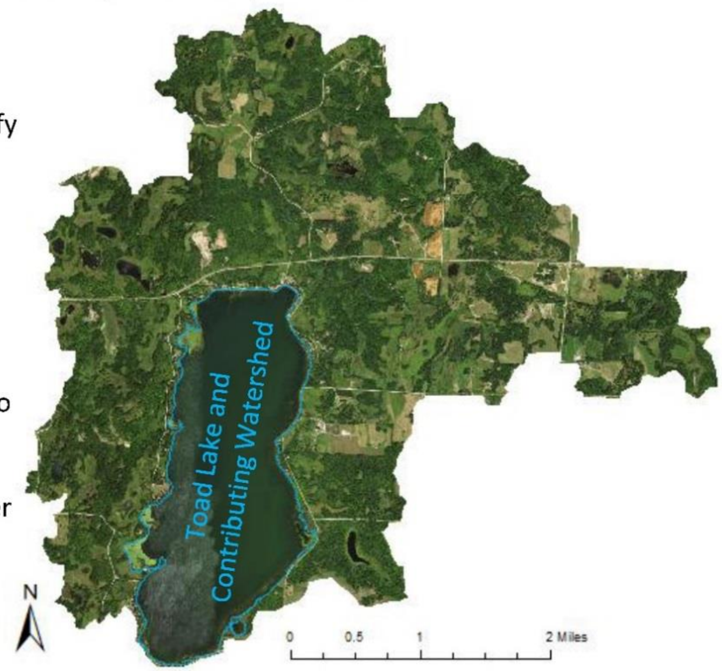
Decreased dissolved oxygen

Decreased DO is not likely contributing to a vulnerable fish community in Toad Lake. A review of DO profile data indicates that depths to approximately 24 to 25 feet (i.e., the bottom of the profile) contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August (**Error! Reference source not found.**). Water temperatures at these depths were warmer than the preferred range of coldwater species such as Burbot; however, Toad Lake does not stratify, or only weakly stratifies, due to its size and depth and therefore would currently lack thermal refuge at these depths irrespective of DO concentration.

Figure 24. Toad Lake (03-0107-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Toad Lake (03-0107-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 42, 45 (3, 0 points below impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Bowfin, Brook Stickleback, Central Mudminnow, Common Shiner, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Least Darter, Mimic Shiner, Northern Pike, Northern Redbelly Dace, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Burbot
- **Inconclusive Causes:**
  - Physical habitat alteration: moderate dock density of 13.4 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 75, Curly-leaf Pondweed and Common Carp present, some permitted aquatic plant removal activity, Toad Lake Dam and several crossings may act as potential barriers to fish passage, downstream Toad River impaired for aquatic life use
  - Altered interspecific competition: Curly-leaf Pondweed and Common Carp present, negative effects of stocking activities or harvest unlikely
  - Temperature regime changes: estimated 1.8 °F increase in mean annual air temperature over last century, water column does not typically stratify
- **Eliminated Causes:**
  - Eutrophication (excess nutrients): 26.6 ppb mean total phosphorus, 15% of contributing watershed classified as unnatural land cover
  - Decreased dissolved oxygen: adequate dissolved oxygen at depths containing suitable temperatures during summer months
- **Recommendations:**
  - No candidate cause identified
  - Evaluate downstream dam and other crossings for potential as barriers to fish passage and restore connectivity as is warranted
  - Follow guidelines in Otter Tail River Watershed Stream Stressor Identification Report to restore aquatic life use in downstream Toad River



5.2. Little Toad Lake (DOW 03-0189-00)

Little Toad Lake is 405 acres in size and has a maximum depth of 65 feet. The littoral zone of the lake covers 26% of the lake area. Little Toad Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Eutrophication, physical habitat alteration, altered interspecific competition, temperature regime changes, and decreased DO have been identified as inconclusive stressors to aquatic life use in Little Toad Lake and will be evaluated further (Figure 27). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Little Toad Lake was sampled using seining and backpack electrofishing during July 2016 and gill netting and trap netting during June 2013. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 46 was above the impairment threshold (45) developed for lakes that are similar to Little Toad Lake (Table 3). An additional nearshore survey was completed in July 2013, but it received insufficient sampling effort due to dense vegetation and difficult sampling conditions and will not be discussed.

During the FIBI survey, 23 fish species were captured (Table 6). The number of omnivore species (i.e., Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, and Yellow Bullhead) was above the level expected for similar lakes as indicated by the respective FIBI metric whereas the proportion of biomass from insectivores (i.e., 11% Bluegill, Pumpkinseed, Yellow Perch) in the trap nets was below the level expected for similar lakes. Six intolerant species, two tolerant species, three small benthic dwelling species, and six vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Black Bullhead, Cisco, Green Sunfish, Logperch, Mimic Shiner, Spottail Shiner, and Tadpole Madtom (Table 6). Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 6). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 two additional species have been sampled in Little Toad Lake. Three Smallmouth Bass were sampled in a MNDNR Fisheries survey in 1977 and one Burbot was sampled in a MNDNR Fisheries survey in 1985, but these species have not been observed in MNDNR surveys since that time (MNDNR 2018c).

Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to a vulnerable fish community in Little Toad Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 22.9 ppb (N=21), chlorophyll-a is 6.4 ppb (N=21), and Secchi transparency is 12.1 feet (N=145) in Little Toad Lake.

These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 7,716 acres within the contributing watershed, 37.1% is classified as unnatural land cover (i.e., 32.4% agricultural, 4.1% developed, and 0.6% barren). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 62% of the agricultural land within Little Toad Lake's contributing watershed is cultivated whereas 38% is hay and pasture land. Seven feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Little Toad Lake. In 1998, individual sewage treatment systems on 50 parcels surrounding the lake were inventoried and 23 were deemed non-compliant. When compliance was last evaluated in 2004, all but five had been updated (BSWCD 2014). Therefore, parcels surrounding the lake should be prioritized for future inspections to ensure compliance continues to be met. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Little Toad Lake, as indicated by a watershed-to-lake ratio of 19.0:1. The combination of a large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

One AMA exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to a vulnerable fish community in Little Toad Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 72, is moderate within Little Toad Lake and slightly below the statewide average score of 73. Development has had the largest effect on the shoreline and aquatic habitat components. A lower shoreline score may indicate that removal of trees, shrubs, and natural ground cover from the water's edge to the bank has most likely occurred in some areas around the lake. Removal of riparian vegetation oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. A lower aquatic score may indicate that removal of floating-leaf vegetation, emergent vegetation, and downed woody habitat from the lake has likely occurred in some areas. These features serve as important habitat for fishes and other aquatic organisms. One effective way to protect shoreline is through acquisition of AMAs. One parcel totaling eight acres is included in the Little Toad Lake AMA; however, most of this parcel is not located along the immediate shoreline of the lake.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Little Toad Lake. According to MPARS, at least 16 properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 60 docks (14.4 docks per mile of shoreline) were present on Little Toad Lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate.

Common Carp and Curly-leaf Pondweed, two non-native species, are present in Little Toad Lake. Recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented.

The water level in Little Toad Lake has varied by 2.2 feet between 1944–2019 and is regulated by a Works Progress Administration dam constructed in 1937 (MNDNR, unpublished data). The dam is 10 feet wide and was authorized to have 2.8 feet of stop logs in place. Potential effects to aquatic life within the lake as a result of the dam are uncertain; however, future investigation may be warranted to restore and/or maintain connectivity to the downstream watershed. If the dam is determined to act as a significant barrier, actions should be considered to restore connectivity. MPCA has also identified that the Toad River downstream of Little Toad Lake is impaired for aquatic life use and has identified several stressors to this reach including loss of longitudinal connectivity, insufficient physical habitat, and high suspended sediment (MPCA 2019). Potential effects to aquatic life within Little Toad Lake are uncertain; however, future investigation may be warranted to restore and/or maintain connectivity within the downstream watershed.

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Little Toad Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities.

Curly-leaf Pondweed and Common Carp are both present within Little Toad Lake. Direct competition of Curly-leaf Pondweed with the fish community is unlikely; however, Common Carp have the potential to displace other native fish species if they occur at high densities. Catch rates from recent surveys would indicate that they are occurring at relatively low densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Little Toad Lake had been stocked with bass, crappie, Northern Pike, sunfish, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 1.0 pounds per littoral acre in even years, as described in the 2015 lake management plan (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.

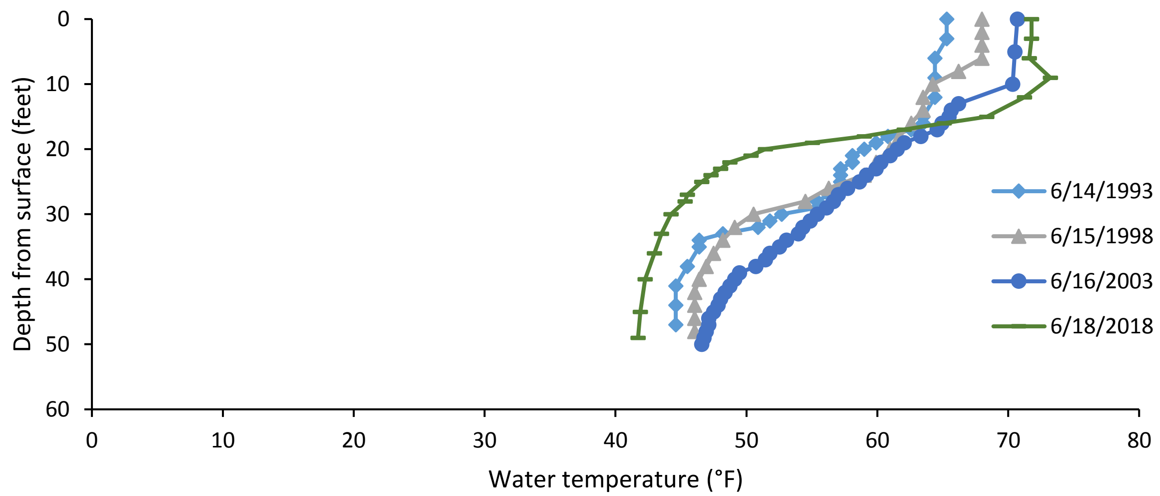
Relative abundance of adult Walleye in Little Toad Lake has been somewhat variable and is currently lower than the lake class inner quartile range, indicating that the fish community has not shifted towards being dominated by Walleye as a result of stocking (MNDNR, unpublished data).

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 Little Toad Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. However, special regulations were initiated in 2008 in an attempt to increase the size structure of Northern Pike and sunfish. Commercial harvest, primarily of bullheads but including Burbot, Bowfin, Common Carp, and suckers, also occurred between 1947 and 2003, but this has likely had little effect on current fish community structure.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to a vulnerable fish community in Little Toad Lake; however, this has been identified as an inconclusive stressor because temperature and oxygen profile data are not available for the month of August, when coldwater habitat is generally most limited in stratified lakes. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.9 °F over the last century as a result of climate change, which is approximately 0.6 °F warmer than for other lakes in the state (Jacobson et al. 2017). June water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1993 and 2018 to evaluate habitat for coldwater species (Figure 25). One coldwater species (i.e., Burbot) that would positively influence the FIBI score has historically been documented in Little Toad Lake. Their absence from recent surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures, although this would be better evaluated with profiles collected in August. An alternative explanation for their absence could be that Burbot are not frequently sampled with traditional gears. Regardless, consideration should be given to collect future temperature and oxygen profiles in August to better evaluate coldwater habitat availability in Little Toad Lake.

Figure 25. June water temperature (°F) by depth within Little Toad Lake (DOW 03-0189-00).



Decreased dissolved oxygen

Decreased DO has the potential to be contributing to a vulnerable fish community in Little Toad Lake; however, it has been identified as an inconclusive stressor because temperature and oxygen profile data are not available for the month of August, when coldwater habitat is generally most limited in stratified lakes. A review of DO profile data indicates that depths to approximately 23 to 31 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of June (Figure 27). Water temperatures at these depths were within the preferred range of coldwater species such as Burbot; however, profiles taken during the month of August would better inform conditions during the most stressful period of the summer for coldwater species. The low levels of oxygen at deeper depths even during the month of June indicate that limited coldwater habitat might be available during months like August, when water temperatures at depth are typically warmest. The low levels of oxygen at deeper depths could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 26. June dissolved oxygen concentration (ppm) by depth within Little Toad Lake (DOW 03-0189-00).

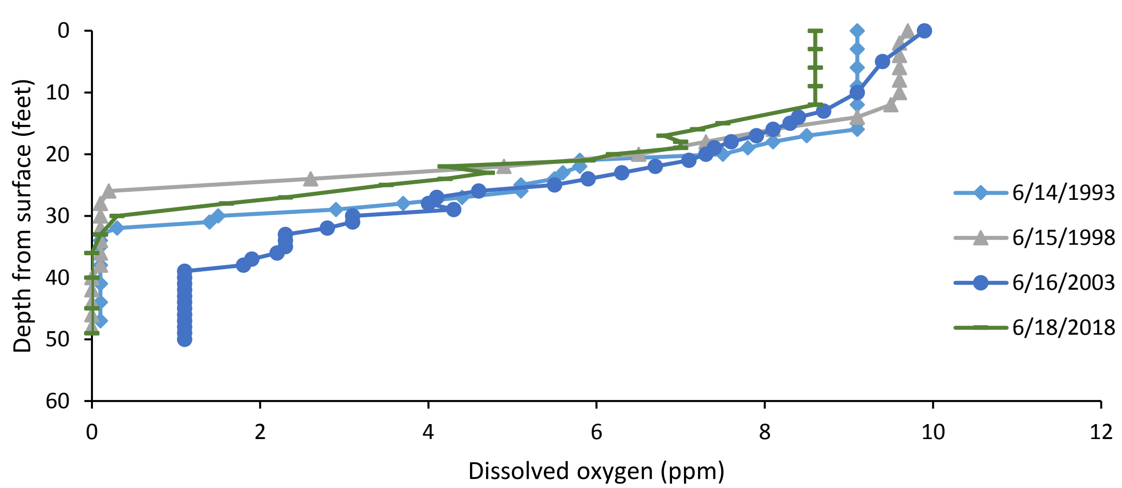
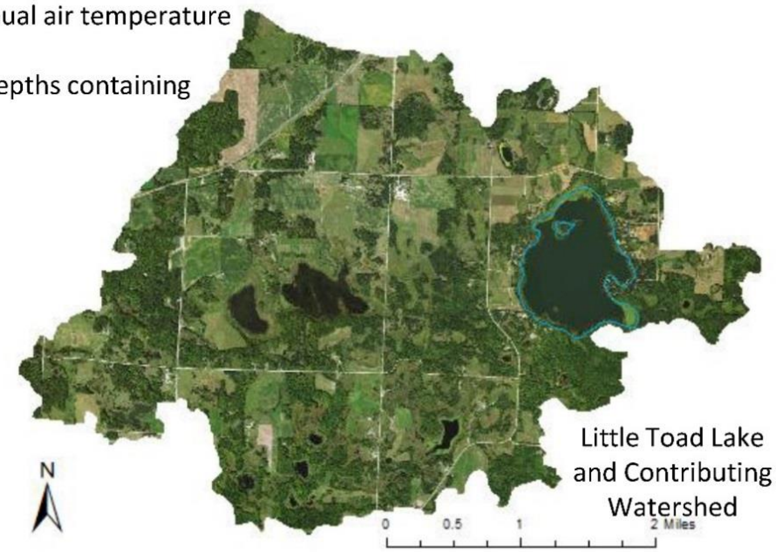


Figure 27. Little Toad Lake (03-0189-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Little Toad Lake (03-0189-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 46 (1 point above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Bowfin, Brook Stickleback, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Least Darter, Northern Pike, Pumpkinseed, Rock Bass, Walleye, Yellow Perch
  - Other species that have previously been sampled: Burbot, Smallmouth Bass
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 22.9 ppb mean total phosphorus, 37% of contributing watershed classified as unnatural land cover
  - Physical habitat alteration: moderate dock density of 14.4 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 72, Curly-leaf Pondweed and Common Carp present, some permitted aquatic plant removal activity, Little Toad Lake Dam and several crossings may act as potential barriers to fish passage, downstream Toad River impaired for aquatic life use
  - Altered interspecific competition: Curly-leaf Pondweed and Common Carp present, negative effects of stocking activities or harvest unlikely
  - Temperature regime changes: estimated 1.9 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: adequate dissolved oxygen at limited depths containing suitable temperatures during summer months
- **Recommendations:**
  - No candidate cause identified
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - Evaluate downstream dam and other crossings for potential as barriers to fish passage and restore connectivity as is warranted
  - Follow guidelines in Otter Tail River Watershed Stream Stressor Identification Report to restore aquatic life use in downstream Toad River



5.3. Acorn Lake (DOW 03-0258-00)

Acorn Lake is 126 acres in size (excluding the north basin) and has a maximum depth of 55 feet. The littoral zone of the lake covers 33% of the lake area. Acorn Lake is scored with FIBI tool 4. Lakes scored with this tool are characterized as generally deep with simple (i.e., round) shorelines, less than 80% littoral area, and moderate species richness (Table 1).

Temperature regime changes and decreased DO have been identified as likely stressors to aquatic life use in Acorn Lake and will be evaluated further. Conversely, eutrophication and physical habitat alteration have been identified as inconclusive and altered interspecific competition has been eliminated as a candidate cause (Figure 30). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Acorn Lake was sampled using seining and backpack electrofishing during July 2016 and gill netting and trap netting during June 2013. The health of the fish community was evaluated using these data and FIBI tool 4. The FIBI score of 39 was above the impairment threshold (38) developed for lakes that are similar to Acorn Lake (Table 3). An additional nearshore survey was completed in July 2013, but it received insufficient sampling effort due to dense Chara sp. and difficult sampling and will not be discussed.

During the FIBI survey, 25 fish species were captured (Table 7). The proportion of biomass from top carnivores (i.e., 40% Black Crappie, Bowfin, Largemouth Bass, Northern Pike, and Walleye) in the gill nets was below the level expected for similar lakes as indicated by the respective FIBI metric. Four intolerant species, three tolerant species, four small benthic dwelling species, and seven vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 4 include Blacknose Shiner, Green Sunfish, and Rock Bass (Table 7). Conversely, species such as Common Carp and Fathead Minnow are generally not sampled in similar lakes that contain healthy fish communities (Table 7). These species have the potential to affect several FIBI metric scores, both positively and negatively.

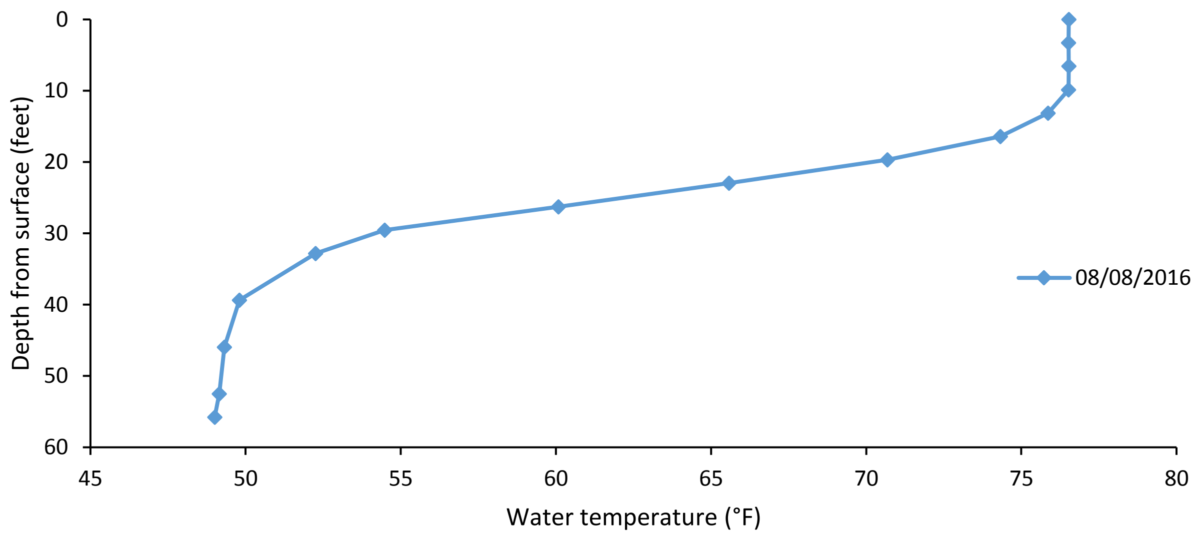
Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. However, historic data indicates that at least one additional species has been sampled in Acorn Lake. Cisco were sampled in MNDNR Fisheries surveys conducted between 1955 and 1983, but they have not been observed in MNDNR surveys since that time (MNDNR 2018c).

Data analysis/Evaluation for each candidate cause

Temperature regime changes

Temperature regime changes are likely occurring at a level that would contribute to a vulnerable fish community in Acorn Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 2.1 °F over the last century as a result of climate change, which is approximately 0.8 °F warmer than for other lakes in the state (Jacobson et al. 2017). Summer water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1993 and 2018 to evaluate habitat for coldwater species, but only one profile has been collected during the month of August when coldwater habitat is most limited (Figure 28). One coldwater species (i.e., Cisco) that would positively influence the FIBI score has historically been documented in Acorn Lake. Their absence from recent surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures.

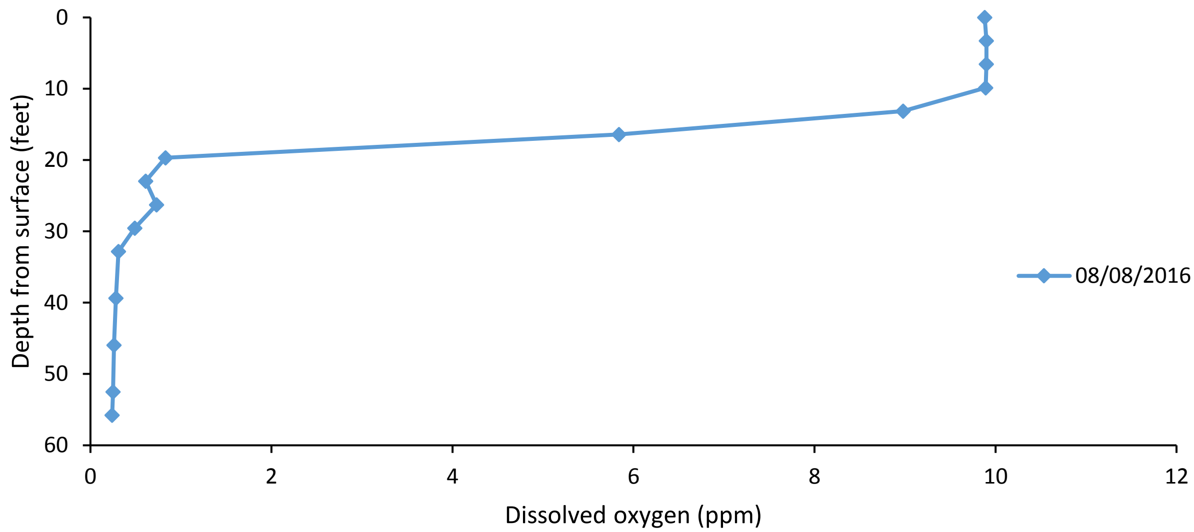
Figure 28. August water temperature (°F) by depth within Acorn Lake (DOW 03-0258-00).



Decreased dissolved oxygen

Decreased DO is likely contributing to a vulnerable fish community in Acorn Lake. A review of DO profile data indicates that depths to approximately 18 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August when the lake was stratified (Figure 29). Water temperatures at these depths were warmer than the preferred range of coldwater species such as Cisco and could be negatively affecting their ability to persist in Acorn Lake. The low levels of oxygen at deeper depths could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 29. August dissolved oxygen concentration (ppm) by depth within Acorn Lake (DOW 03-0258-00).



Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to a vulnerable fish community in Acorn Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 21.6 ppb (N=8), chlorophyll-a is 8.6 ppb (N=8), and Secchi transparency is 12.1 feet (N=8) in Acorn Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 752 acres within the contributing watershed, 30.6% is classified as unnatural land cover (i.e., 20.2% agricultural and 10.4% developed). The percentage of unnatural land cover is approaching 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 within Acorn Lake's contributing watershed is hay and pasture land whereas 4% is cultivated. No feedlots are located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land could contribute excess nutrients into the lake if not properly managed.

Although somewhat limited, residentially developed land within the contributing watershed is predominantly located along the shoreline of Acorn Lake. Data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake; however, these parcels could be prioritized for future inspections to ensure compliance is met and maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Acorn Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 4.9:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low

TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Undeveloped lands, particularly parcels in public ownership that are protected from future development, can 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. Several examples include AMAs and WMAs that are managed by the state, but neither occur within Acorn Lake's contributing watershed.

Physical habitat alteration

Physical habitat alteration does not appear to be occurring at a level that may be negatively affecting the fish community in Acorn Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 78, is moderate within Acorn Lake and above the statewide average score of 73. Development has had a relatively uniform effect on the shoreland, shoreline, and aquatic habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on West Silent Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Acorn Lake. According to MPARS, at least two properties are, or have been, permitted to remove submersed plants via automated aquatic plant control devices to provide riparian access, but data for other sources of removal are lacking. A 2013 survey has documented 14 acres of floating-leaf and emergent vegetation. A historic survey completed in 1984 documented 24 acres of vegetation, but this survey followed slightly different protocols and also included submersed vegetation. Nonetheless, vegetation was present along a majority of the shoreline during both surveys. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 22 docks (9.1 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal may have contributed to some physical habitat loss within the lake, significant changes to the fish community may be unlikely based on the dock density estimate and the relatively large area of floating-leaf and emergent vegetation.

Curly-leaf Pondweed and Common Carp, two non-native species, are present in Acorn Lake. Recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data). Any potential effects on the physical habitat within the lake have not been evaluated or documented.

The water level in Acorn Lake has varied by 1.8 feet between 1937–1997 and has been regulated by a Works Progress Administration dam constructed in 1937 (MNDNR, unpublished data). The dam is 10 feet wide and was authorized to have 1.6 feet of stop logs in place, although at last inspection in 2016 all stop logs may have been permanently removed. Potential effects to aquatic life within the lake as a result of the dam in its current state are unlikely; however, future investigation may be warranted. Several road crossings (i.e., Acorn Lake Road, Indy 500 Road, and State Highway 87) also occur downstream of the outlet, which ultimately connects Acorn Lake to Town Lake and the Otter Tail River; however, they have not been identified as barriers at this time (A. Hillman, MNDNR, personal communication).

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Acorn Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities.

Curly-leaf Pondweed and Common Carp are both present within Acorn Lake. Direct competition of Curly-leaf Pondweed with the fish community is unlikely; however, Common Carp have the potential to displace other native fish species if they occur at high densities. Catch rates from recent surveys would indicate that they are occurring at relatively low densities when compared to other lakes in the same lake class (MNDNR, unpublished data).

Historically, Acorn Lake had been stocked with bass, Black Crappie, Rainbow Trout, sunfish, Northern Pike, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 2.0 pounds per littoral acre in odd years, as described in the 2015 lake management plan (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.

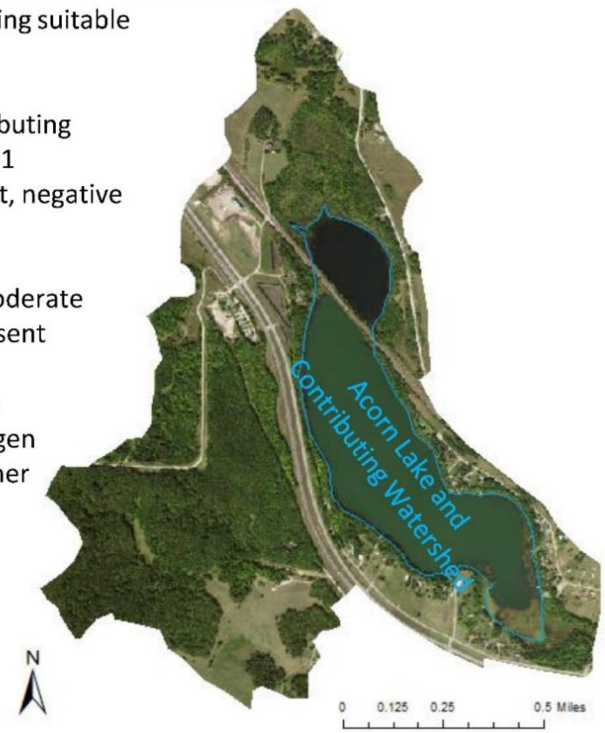
Relative abundances of adult Walleye and Yellow Perch in Acorn Lake have been variable and both are currently higher than the lake class inner quartile range (MNDNR, unpublished data). The high relative abundance of Yellow Perch, a primary forage item for Walleye, would suggest that the fish community has not shifted towards being dominated by Walleye as a result of stocking.

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 Acorn 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. Cisco sport netting was also open seasonally until 1983, when it was closed due to the absence of Cisco from surveys and marginal water quality for coldwater species.

Figure 30. Acorn Lake (03-0258-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Acorn Lake (03-0258-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 39 (1 point above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Bluegill, Bowfin, Brook Stickleback, Central Mudminnow, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Mottled Sculpin, Northern Pike, Pumpkinseed, Spottail Shiner, Tadpole Madtom, Walleye, Yellow Perch
  - Other species that have previously been sampled: Cisco
- **Candidate Causes:**
  - Temperature regime changes: estimated 2.1 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: lack of adequate dissolved oxygen at depths containing suitable temperatures during summer months
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 21.6 ppb mean total phosphorus, 31% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 2.4:1
  - Altered interspecific competition: Curly-leaf Pondweed and Common Carp present, negative effects of stocking activities or harvest unlikely
- **Eliminated Causes:**
  - Physical habitat alteration: low dock density of 7.4 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 78, Curly-leaf Pondweed and Common Carp present
- **Recommendations:**
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover and low dissolved oxygen present at temperatures suitable for coldwater species such as Cisco during summer months



5.4. Cotton Lake (DOW 03-0286-00)

Cotton Lake is 1,783 acres in size and has a maximum depth of 28 feet. The littoral zone of the lake covers 44% of the lake area. Cotton Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration has been identified as a likely stressor to aquatic life use in Cotton Lake and will be evaluated further. Conversely, temperature regime changes has been identified as an inconclusive stressor and eutrophication, altered interspecific competition, and decreased DO have been eliminated as candidate stressors (Figure 33). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Cotton Lake was sampled using seining, backpack electrofishing, gill netting and trap netting during July 2016. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 46 was above the impairment threshold (45) developed for lakes that are similar to Cotton Lake (Table 3).

During the FIBI survey, 23 fish species were captured (Table 6). The proportion of biomass from top carnivores (i.e., 41% Black Crappie, Largemouth Bass, Northern Pike, Rock Bass, and Walleye) in the gill nets was below the level expected for similar lakes as indicated by the respective FIBI metric. Seven intolerant species, three tolerant species, three small benthic dwelling species, and five vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Blackchin Shiner, Bowfin, Golden Shiner, Spottail Shiner, and Tadpole Madtom (Table 6). These species have the potential to positively affect several FIBI metric scores.

Because this is the first time utilizing the 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 Cotton Lake. Blackchin Shiner, Common Shiner, and Hornyhead Chub were sampled in various MNDNR Fisheries surveys between 1992 and 2001, but these species have not been observed in MNDNR surveys since that time (MNDNR 2018c). These historically sampled species may be 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

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to a vulnerable fish community in Cotton Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 65, is low within Cotton Lake and below the statewide average score of 73. Development has had an effect on the shoreland, shoreline, and aquatic habitat components although the largest effect has been on the shoreline. A lower shoreline score may indicate that removal of trees, shrubs, and natural ground cover from the water's edge to the bank has most likely occurred in some areas around the lake. Removal of riparian vegetation oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. Several parcels totaling 111 acres are included in the Cotton Lake AMA and Shelly Island WMA that protect vulnerable shoreline on the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Cotton Lake. According to MPARS, at least 12 properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. Likewise, no floating-leaf and emergent vegetation mapping surveys have been completed to date to evaluate potential changes to those communities. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 272 docks (20.6 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

Purple Loosestrife is the only non-native species present around the lake. No significant changes to the physical habitat resulting from its presence have been documented.

The water level in Cotton Lake is unregulated (i.e., no water control structure) and has varied by 5.2 feet between 1941–2014 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several road crossings (i.e., South Cotton Lake Road, County Highway 32, and several unnamed roads) are present downstream of the outlet, which ultimately connects Cotton Lake to the Otter Tail River. These crossings should be investigated to determine their potential as barriers to fish passage. If these crossings are determined to act as barriers, actions should be considered to restore connectivity.

Information about select inconclusive and eliminated causes

Eutrophication

Eutrophication is not likely occurring at a level that would contribute to a vulnerable fish community in Cotton Lake based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 18.8 ppb (N=9), chlorophyll-a is 6.0 ppb (N=9), and Secchi transparency is 9.6 feet (N=180) in Cotton Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Of the 8,508 acres within the contributing watershed, 17.8% is classified as unnatural land cover (i.e., 12.9% agricultural, 4.0% developed, and 0.8% barren). The percentage of unnatural land cover is below a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 61% of agricultural land within Cotton Lake's contributing watershed is cultivated whereas 39% is hay and pasture land. One feedlot is also located within the contributing watershed (MPCA 2016). Although not identified as a stressor, surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake in the future if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shorelines of Cotton and Pickerel lakes. In 1994, individual sewage treatment systems on 236 parcels surrounding the lake were inventoried and 51 were deemed non-compliant. When compliance was last evaluated in 2004, all but one had been updated (BSWCD 2014). Therefore, parcels surrounding the lake should be prioritized for future inspections, if they have not already been completed, to ensure compliance continues to be met. Although not identified as a stressor, runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake in the future if not properly managed.

Although eutrophication has been identified as an eliminated cause, Cotton Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 4.8:1. As such, management actions intended to reduce excess nutrient inputs would be relatively targeted and reasonably attainable.

A high percentage of land within the watershed is undeveloped and several parcels are included in AMAs, WMAs, and the Tamarac National Wildlife Refuge. Undeveloped lands, particularly parcels in public ownership 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.

Altered interspecific competition

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

To date, Purple Loosestrife has been the only documented non-native species in the lake, and direct competition with the native fish community is unlikely.

Historically, Cotton Lake had been stocked with Bluegill, Black Crappie, Lake Trout, Largemouth Bass, Northern Pike, and Walleye. MNDNR Fisheries currently stocks Walleye fingerlings at a rate of 1.0 pounds per littoral acre in odd years, as described in the 2018 lake management plan (MNDNR, unpublished data). Private Walleye stocking has also been permitted as recently as 2019. 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.

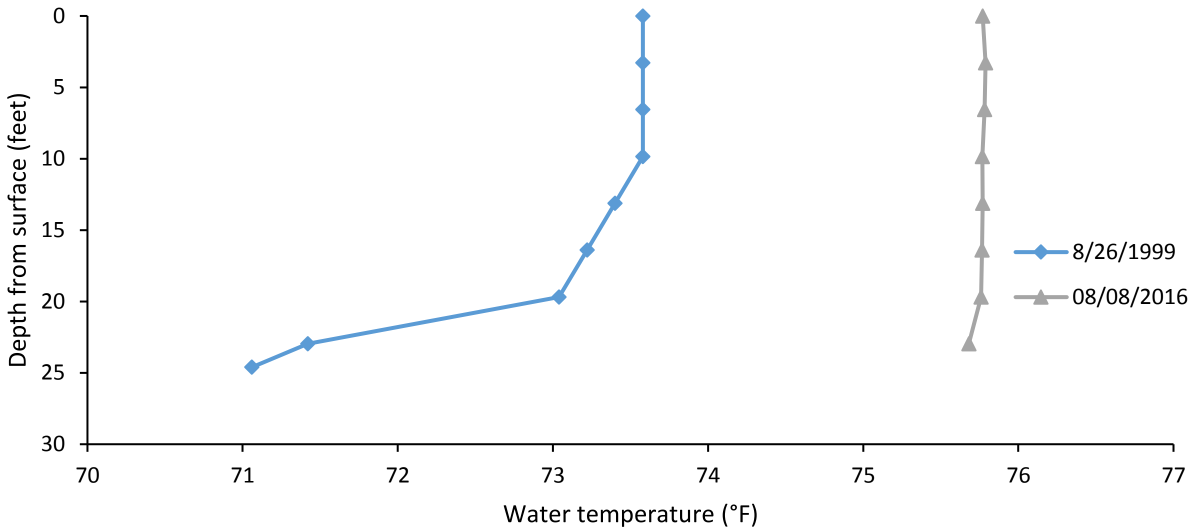
Relative abundances of adult Walleye and Yellow Perch in Cotton Lake have been variable and both are currently within the lake class inner quartile range (MNDNR, unpublished data). The average relative abundance of Yellow Perch, a primary forage item for Walleye, would suggest that the fish community has not shifted towards being dominated by Walleye as a result of stocking.

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 Cotton 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. Other relevant activities include commercial harvest of bullheads that occurred between 1956 and 1957 and Cisco sport netting that remains open seasonally.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to a vulnerable fish community in Cotton Lake; however, this has been identified as an inconclusive stressor based on the lake's morphology, which may naturally limit the ability of coldwater species to persist in the lake. Temperature regime changes are likely occurring at a level that would contribute to a vulnerable fish community in Cotton Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 2.1 °F over the last century as a result of climate change, which is approximately 0.8 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MPCA sampling between 1999 and 2016 to evaluate habitat for coldwater species (Figure 31). One coldwater species (i.e., Cisco) that positively influences the FIBI score is frequently sampled at varying levels in Cotton Lake. Despite this, temperature conditions in the lake may not be favorable for the species during the summer months when coldwater habitat is generally most limited, particularly in lakes such as Cotton Lake that do not stratify, or only weakly stratify, due to their large size relative to their shallow depth.

Figure 31. August water temperature (°F) by depth within Cotton Lake (DOW 03-0286-00).



Decreased dissolved oxygen

Decreased DO is not likely contributing to a vulnerable fish community in Cotton Lake. A review of DO profile data indicates that depths to approximately 23 to 24 feet (i.e., the bottom of the profile) contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August (Figure 32). Water temperatures at these depths were warmer than the preferred range of coldwater species such as Cisco; however, Cotton Lake does not stratify, or only weakly stratifies, due to its size and depth and therefore would currently lack thermal refuge at these depths irrespective of DO concentration.

Figure 32. August dissolved oxygen concentration (ppm) by depth within Cotton Lake (DOW 03-0286-00).

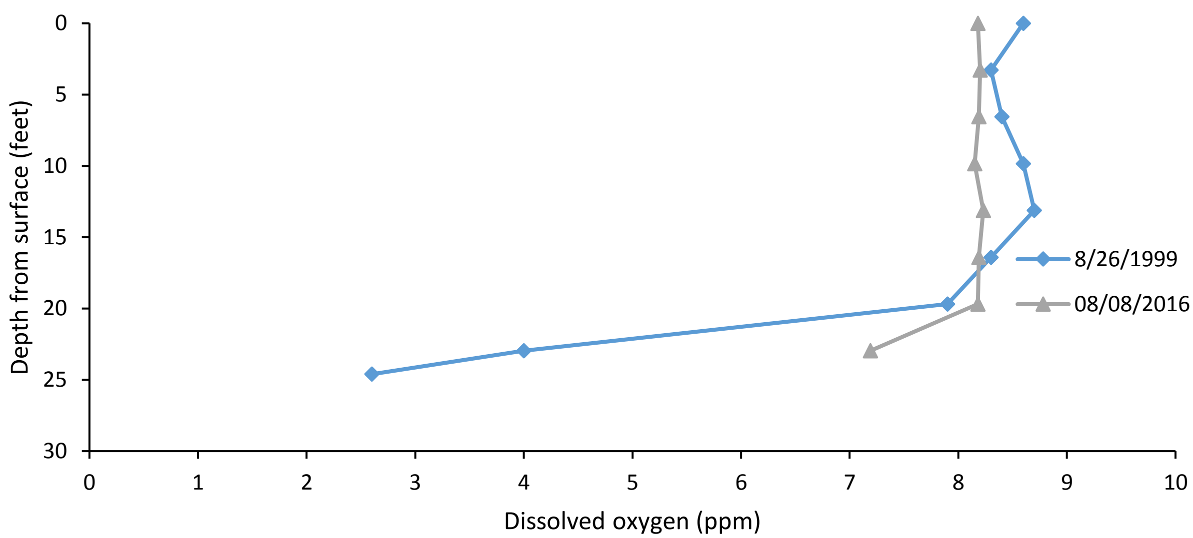
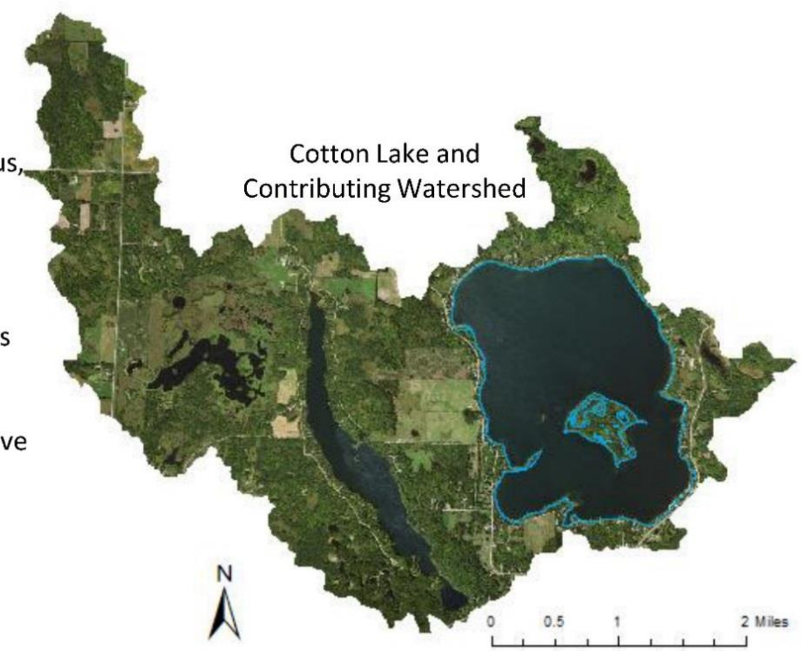


Figure 33. Cotton Lake (03-0286-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Cotton Lake (03-0286-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI score: 46 (1 point above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blacknose Shiner, Bluegill, Cisco, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Mimic Shiner, Northern Pike, Pumpkinseed, Rock Bass, Spottail Shiner, Walleye, Yellow Perch
  - Other species that have previously been sampled: Blackchin Shiner, Common Shiner, Hornyhead Chub
- **Candidate Causes:**
  - Physical habitat alteration: high dock density of 20.6 docks per mile of shoreline, low lakewide Score the Shore (StS) of 65, Purple Loosestrife present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
- **Inconclusive Causes:**
  - Temperature regime changes: estimated 2.1 °F increase in mean annual air temperature over last century, water column does not typically stratify
- **Eliminated Causes:**
  - Eutrophication (excess nutrients): 18.8 ppb mean total phosphorus, 18% of contributing watershed classified as unnatural land cover, small watershed-to-lake ratio of 4.8:1
  - Altered interspecific competition: Purple Loosestrife present, negative effects of stocking activities or harvest unlikely
  - Decreased dissolved oxygen: adequate dissolved oxygen at depths containing suitable temperatures during summer months
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Evaluate downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



5.5. Lake Sallie (DOW 03-0359-00)

Lake Sallie is 1,273 acres in size and has a maximum depth of 50 feet. The littoral zone of the lake covers 45% of the lake area. Lake Sallie is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Eutrophication and physical habitat alteration have been identified as likely stressors to aquatic life use in Lake Sallie and will be evaluated further. Conversely, altered interspecific competition, temperature regime changes, and decreased DO have been identified as inconclusive stressors (Figure 36). 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 Sallie was sampled using seining and backpack electrofishing during July 2014 and 2016, gill netting and trap netting during July 2014. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 51 in 2016 was above the impairment threshold (45) developed for lakes that are similar to Lake Sallie whereas the FIBI score of 44 in 2014 was below the impairment threshold (Table 3).

During the FIBI surveys, 31 fish species were captured (Table 6). The number of omnivores (i.e., Black Bullhead, Brown Bullhead, White Sucker, and Yellow Bullhead) exceeded the level expected for similar lakes as indicated by the respective FIBI metric. Nine intolerant species, three tolerant species, four small benthic dwelling species, and eleven vegetative dwelling species were sampled.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Commercial harvest records indicate that Burbot have historically been sampled in Lake Sallie. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c). Likewise, Muskellunge and Lake Sturgeon have also been observed, although they may not be documented by standard MNDNR gill net and trap net efforts.

Data analysis/Evaluation for each candidate cause

Eutrophication

Eutrophication has and may still be occurring at a level that would contribute to a vulnerable fish community in Lake Sallie based on review of relevant water quality and watershed disturbance information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 29.7 ppb (N=41), chlorophyll-a is 10.9 ppb (N=39), and Secchi transparency is 7.3 feet (N=211) in Lake Sallie. These parameters indicate that the lake is likely receiving inputs of excess nutrients that could negatively affect the fish community.

Of the 58,553 acres within the contributing watershed, 41.5% is classified as unnatural land cover (i.e., 30% agricultural, 10.5% developed, and 1.0% barren). 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 56% of the agricultural land within Lake Sallie's contributing watershed is cultivated whereas 44% is hay and pasture land. Twenty-three feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could be contributing excess nutrients (e.g., TP) into the lake.

Historically, Lake Sallie was enriched by sewage effluent from the city of Detroit Lakes. Changes in city water treatment have greatly improved the quality of water entering the lake since that time, and some shifts in the composition of the game fish community (e.g., reestablishment of Cisco and decline in Black Bullhead and Black Crappie) as outlined in the lake management plan would further indicate that the changes are working (MNDNR, unpublished data).

In addition to the city of Detroit Lakes, some of the residentially developed land within the contributing watershed is located along the shoreline of Lake Sallie. In 2009, individual sewage treatment systems on 257 parcels surrounding the lake were inventoried and all have been deemed compliant since that time (K. Vareberg, Becker County Zoning, personal communication). Runoff from lawns and discharge from failing individual sewage treatment systems could be contributing excess nutrients into the lake.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Lake Sallie, as indicated by a watershed-to-lake ratio of 45.8:1. The combination of a 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 AMAs, WPAs, and WMAs do exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to a vulnerable fish community in Lake Sallie based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 66, is low within Lake Sallie and below the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. Several parcels totaling 102 acres are included in the Sallie Lake and Detroit Lakes Headquarters AMAs that protect vulnerable shoreline on the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Lake Sallie. According to MPARS, at least 27 properties are, or have been, permitted to remove submersed and emergent plants via automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. A 2015 survey has documented 45 acres of floating-leaf and emergent vegetation. A historic survey completed in 1985 documented 52 acres of vegetation, but this survey followed slightly different protocols and also included submersed vegetation. Nonetheless, vegetation was present along similar reaches of the shoreline during both surveys, with the exception of an area along the northwest shoreline that may have historically contained bulrush stands. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 167 docks (29.0 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the relatively small area of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

Zebra Mussels, Curly-leaf Pondweed, and Flowering Rush, three non-native species, are present in Lake Sallie. Pelican River Watershed District operated a mechanical harvester to control Curly-leaf Pondweed until 2017 and has also led efforts for scale chemical treatment of Curly-leaf Pondweed and Flowering Rush. No significant changes to the fish community resulting from these species' presence or their effects on physical habitat have been documented or evaluated.

The Pelican River is the primary inlet and outlet for Lake Sallie. The water level has varied by 5.6 feet between 1935–2019 and is regulated by the state-owned dam at Shoreham, which was modified to a fish passable rock arch rapids in 2003 (MNDNR, unpublished data). The inlet, also a state-owned dam at the historic Dunton Locks site, was modified for fish passage in 2002. The result of these two projects has restored connectivity and fish passage along the Pelican River from Mill Lake through Melissa, Sallie, Muskrat, and Detroit lakes. An additional dam in the downstream watershed, Bucks Mill Dam, is still in operation and acts as a barrier to fish passage along the Pelican River. Modifications to the dam will eventually be needed to address safety, failing infrastructure, and fish passage. Other potential barriers to fish passage (e.g., culverts or bridges) may exist within the watershed; however, negative effects to Lake Sallie's fish community resulting from their presence are unlikely, particularly as other waterbodies that are directly connected to Lake Sallie (i.e., Detroit and Melissa lakes) contain healthy fish communities.

Information about select inconclusive causes

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Lake Sallie based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities. However, altered interspecific competition has been identified as an inconclusive stressor.

Zebra Mussels, Flowering Rush, and Curly-leaf Pondweed are present within Lake Sallie. Direct competition with the native fish community by Flowering Rush and Curly-leaf Pondweed is unlikely; however, the effects of Zebra Mussels have not been documented or evaluated.

Historically, Lake Sallie had been stocked with Bluegill, Black Crappie, bullheads, Fathead Minnow, Largemouth Bass, Muskellunge, Northern Pike, Rock Bass, Smallmouth Bass, White Sucker, and Walleye. MNDNR Fisheries currently stocks 2,500,000 Walleye fingerlings annually and has a contingency stocking plan that would allow for an additional 1.0 pounds of fingerlings per acre to be stocked every other year, as described in the 2016 lake management plan (MNDNR, unpublished data). This stocking protocol has been established because Lake Sallie serves as a Walleye egg-take site. 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.

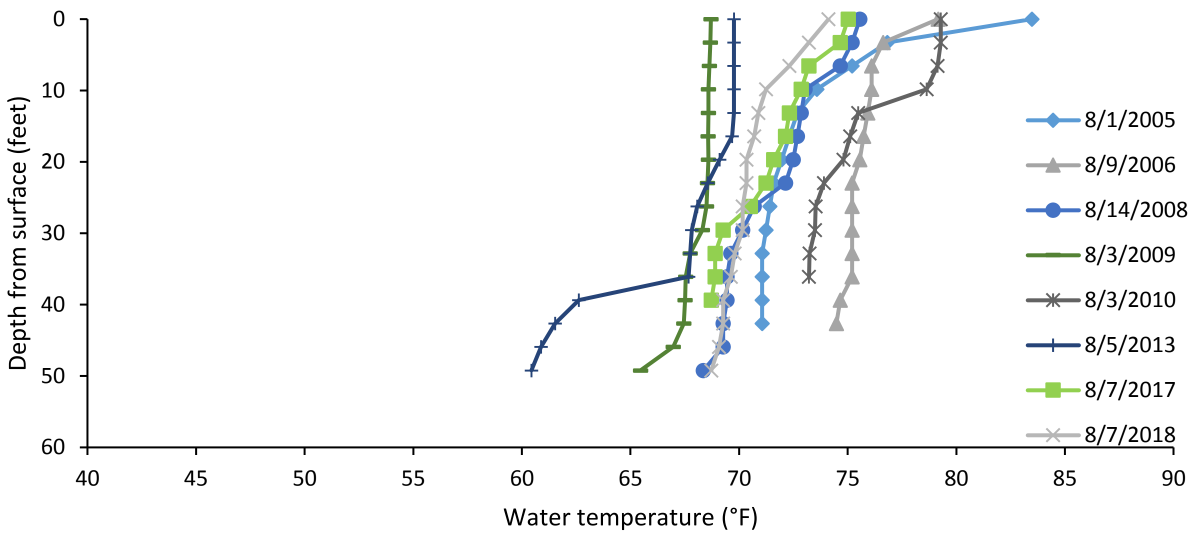
Relative abundance of adult Walleye in Lake Sallie has been variable and is currently higher than the lake class inner quartile range. Relative abundance of Yellow Perch has also been variable and is currently within the lake class inner quartile range (MNDNR, unpublished data). The average relative abundance of Yellow Perch, a primary forage item for Walleye, would suggest that the fish community has not shifted towards being dominated by Walleye as a result of stocking.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest were quantified during two creel surveys conducted in 1994–1995 and 2003–2004, although these surveys focused primarily on Northern Pike management (Erickson 2005). When compared to historical creel surveys for other similar lakes, angler effort and Northern Pike catch rates were below the 50th percentile. These statistics were also relatively similar when comparing between the two surveys conducted on Lake Sallie. Results from these surveys were used to inform Northern Pike management decisions including a special regulation, which is currently used to improve and maintain size structure of Northern Pike. The creel survey results and special regulation may reflect some concern about angler harvest and its effect on fish community composition through altered interspecific competition. Other relevant activities include commercial harvest, primarily of bullheads but including Bowfin, Burbot, and White Sucker, that occurred between 1944 and the present and Cisco sport netting that remains open seasonally.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to an impaired fish community in Lake Sallie; however, this has been identified as an inconclusive stressor because one coldwater species that would be strongly affected by this stressor was sampled during the FIBI surveys. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 2.2 °F over the last century as a result of climate change, which is approximately 0.9 °F warmer than for other lakes in the state (Jacobson et al. 2017). Early August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MPCA sampling between 1996 and 2018 to evaluate habitat for coldwater species (Figure 34). Two coldwater species that positively influence the FIBI score have historically been documented in Lake Sallie. Cisco are frequently sampled at varying levels whereas Burbot have only been recorded in commercial catch. Despite this, temperature conditions in the lake may not be favorable for either species in the future if summer water temperatures continue to increase, particularly in lakes such as Lake Sallie that are considered polymictic and only weakly stratify due to their large size relative to their shallow depth.

Figure 34. August water temperature (°F) by depth within Lake Sallie (DOW 03-0359-00).



Decreased dissolved oxygen

Decreased DO has the potential to be contributing to a vulnerable fish community in Lake Sallie; however, it has been identified as an inconclusive stressor. A review of DO profile data indicates that depths to approximately 19 to 43 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August (Figure 35). In some years where DO was less than 3 ppm at shallower depths, water temperatures at those depths were warmer than the preferred range of coldwater species such as Cisco and Burbot and could be negatively affecting their ability to persist in Lake Sallie. Because Lake Sallie is polymictic, or only weakly stratified during the summer months, water temperature may have a larger influence on available coldwater habitat than DO concentration. Nonetheless, the low levels of oxygen at deeper depths during some years could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter. Future increases in summer water temperature or inputs of excess nutrients, subsequent decomposition of the resulting organic matter, and reduced DO concentrations have the potential to negatively affect the species' ability to persist in Lake Sallie.

Figure 35. August dissolved oxygen concentration (ppm) by depth within Lake Sallie (DOW 03-0359-00).

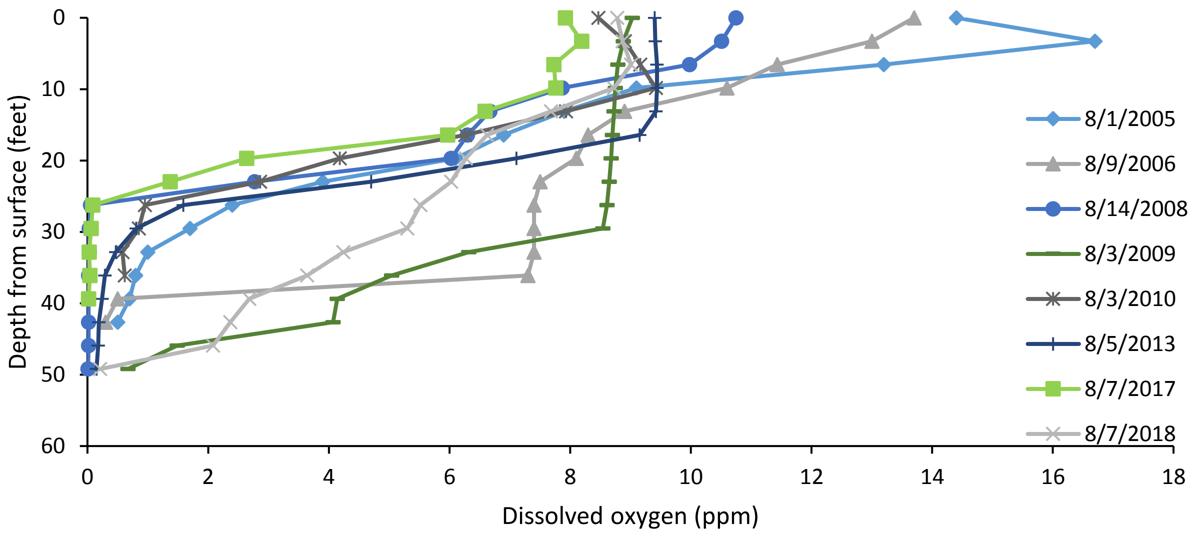


Figure 36. Lake Sallie (03-0359-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Lake Sallie (03-0359-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 44, 51 (1 point below, 6 points above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Bowfin, Brook Stickleback, Central Mudminnow, Cisco, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Mimic Shiner, Northern Pike, Pugnose Shiner, Pumpkinseed, Rock Bass, Spottail Shiner, Tadpole Madtom, Walleye, Weed Shiner, Yellow Perch
  - Other species that have previously been sampled: Burbot, Lake Sturgeon, Muskellunge
- **Candidate Causes:**
  - Eutrophication (excess nutrients): 29.7 ppb mean total phosphorus, 42% of contributing watershed classified as unnatural land cover, historic enrichment by sewage effluent from city of Detroit Lakes, large watershed-to-lake ratio of 45.8:1
  - Physical habitat alteration: very high dock density of 29.0 docks per mile of shoreline, low lakewide Score the Shore (StS) of 66, Zebra Mussels, Curly-leaf Pondweed, and Flowering Rush present, some permitted aquatic plant removal activity, fish passage restored at several sites
- **Inconclusive Causes:**
  - Altered interspecific competition: Zebra Mussels, Curly-leaf Pondweed, and Flowering Rush present, negative effects of stocking activities or harvest unlikely
  - Temperature regime changes: estimated 2.2 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: lack of adequate dissolved oxygen at depths containing suitable temperatures during summer months in some years
- **Recommendations:**
  - Use best management practices to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation

Sallie Lake and Contributing Watershed

5.6. Big Cormorant Lake (DOW 03-0576-00)

Big Cormorant Lake is 3,657 acres in size and has a maximum depth of 75 feet. The littoral zone of the lake covers 22% of the lake area. Big Cormorant Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Physical habitat alteration, temperature regime changes, and decreased DO have been identified as likely stressors to aquatic life use in Big Cormorant Lake and will be evaluated further. Conversely, eutrophication and altered interspecific competition have been identified as inconclusive stressors (Figure 39). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Big Cormorant Lake was sampled using seining and backpack electrofishing during September 2014 and August 2015 and gill netting and trap netting during July 2014. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 46 in 2015 was above the impairment threshold (45) developed for lakes that are similar to Big Cormorant Lake whereas the FIBI score of 41 in 2014 was below the impairment threshold (Table 3).

During the FIBI surveys, 28 fish species were captured (Table 6). The number of omnivores (i.e., Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, White Sucker, and Yellow Bullhead) exceeded the level expected for similar lakes as indicated by the respective FIBI metric. Nine intolerant species, three tolerant species, three small benthic dwelling species, and seven vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Bowfin, Cisco, Fathead Minnow, Golden Shiner, and Tadpole Madtom. Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 6). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the FIBI protocols in the lake assessment process, historical surveys of similar rigor are unavailable to facilitate comparison of fish species assemblages through time. Commercial harvest records indicate that Burbot have historically been sampled in Big Cormorant Lake. Previous MNDNR Fisheries surveys captured a similar suite of game fish species, but nongame species were not well documented (MNDNR 2018c). Although not part of the fish community or considered during the assessment process, Mudpuppies are also present within Big Cormorant Lake, and there have been large-scale die offs in recent years. The cause of these die offs is under investigation.

Data analysis/Evaluation for each candidate cause

Physical habitat alteration

Physical habitat alteration is likely occurring at a level that would contribute to a vulnerable fish community in Big Cormorant Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 67, is moderate within Big Cormorant Lake and below the statewide average score of 73. Development has had the largest effect on the shoreland and shoreline habitat components, which indicates that replacement of trees, shrubs, and natural ground cover with open yards has most likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs. One parcel totaling 16 acres is included in the Big Cormorant Lake-Dudley Farnham/Henry Bolley AMA that protects vulnerable shoreline on the lake from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Big Cormorant Lake. According to MPARS, at least 12 properties are, or have been, permitted to remove submersed plants via automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. A 2015 survey has documented 13 acres of floating-leaf and emergent vegetation, but no historic surveys of similar rigor have been completed for comparative purposes. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2015 Google imagery indicates that approximately 641 docks (34.2 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Based on the dock density estimate and the relatively small area of floating-leaf and emergent vegetation, aquatic plant removal has likely contributed to some physical habitat loss within the lake, which could result in changes to the fish community as evaluated by the FIBI.

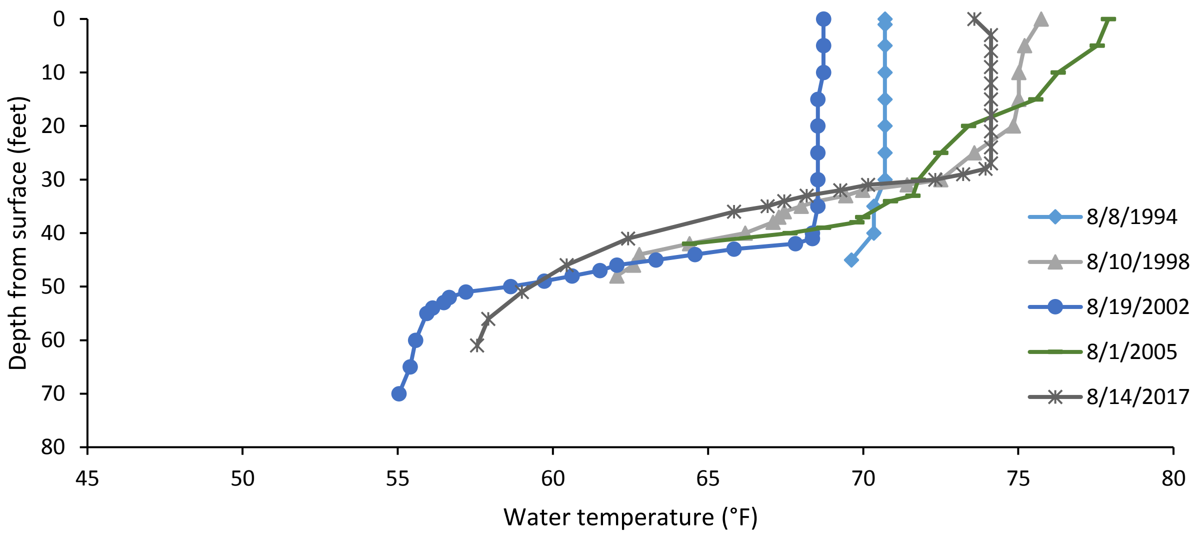
Zebra Mussels (2015), Common Carp, and Chinese Mystery Snails, three non-native species, are present in Big Cormorant Lake. Any potential effects of these species on the physical habitat within the lake have not been evaluated or documented; however, recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data).

The water level in Big Cormorant Lake is unregulated (i.e., no water control structure) and has varied by 10.3 feet between 1953–2019 (MNDNR, unpublished data). No culverts or bridges within the contributing watershed have been inventoried or documented in the MDOT Bridge and Culvert Inventory or the MNDNR Culvert Inventory. However, several crossings (i.e., County Highway 1, several field crossings, Golden Lane, Swanies Creek Road, and County Highway 5) do occur upstream of the inlet, which ultimately connects Big Cormorant Lake to Middle Cormorant, Nelson, Upper Cormorant, and Bijou lakes. Similarly, several crossings (i.e., South Big Cormorant Road and several unnamed crossings) occur downstream of the outlet. The outlet also has a fish barrier near the lake. One additional culvert further downstream at the connection with Pelican Lake (i.e., County Highway 9) has been identified as a potential barrier as cattails may be blocking passage (A. Hillman, MNDNR, unpublished data). These crossings should be investigated to determine their potential as barriers to fish passage. If these crossings are determined to act as barriers, actions should be considered to restore connectivity.

Temperature regime changes

Temperature regime changes are likely occurring at a level that would contribute to an impaired fish community in Big Cormorant Lake. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 2.0 °F over the last century as a result of climate change, which is approximately 0.7 °F warmer than for other lakes in the state (Jacobson et al. 2017). August water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1994 and 2017 to evaluate habitat for coldwater species (Figure 37). One coldwater species (i.e., Burbot) that would positively influence the FIBI score has been documented in Big Cormorant Lake by commercial fishermen. Their absence from MNDNR surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures, or it could also be an artifact that Burbot are not frequently sampled with traditional gears.

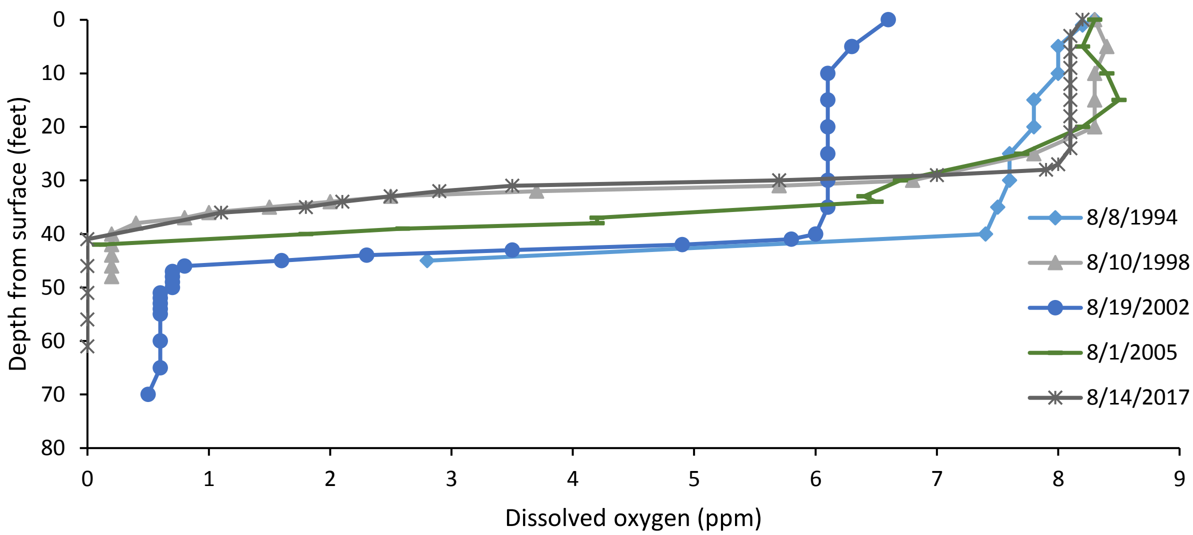
Figure 37. August water temperature (°F) by depth within Big Cormorant Lake (DOW 03-0576-00.



Decreased dissolved oxygen

Decreased DO is likely contributing to an impaired fish community in Big Cormorant Lake. A review of DO profile data indicates that depths to approximately 32 to 44 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of August when the lake was stratified (Figure 38). Water temperatures at these depths were warmer than the preferred range of coldwater species such as Burbot and could be negatively affecting their ability to persist in Big Cormorant Lake. The low levels of oxygen at deeper depths could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 38. August dissolved oxygen concentration (ppm) by depth within Big Cormorant Lake (DOW 56-0576-00).



Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to a vulnerable fish community in Big Cormorant Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 14.5 ppb (N=41), chlorophyll-a is 3.6 ppb (N=41), and Secchi transparency is 16.8 feet (N=41) in Big Cormorant Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 22,849 acres within the contributing watershed, 39.5% is classified as unnatural land cover (i.e., 34.2% agricultural, 5.1% developed, and 0.2% barren). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013). In addition to relatively high land use disturbance in the contributing watershed, one upstream water body (i.e., Upper Cormorant Lake) contains relatively high nutrient levels (i.e., 33.3 ppb TP) and is also impaired for aquatic life use.

Approximately 51% of the agricultural land within Big Cormorant Lake's contributing watershed is hay and pasture land whereas 49% is cultivated. Six feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land within the contributing watershed is predominantly located along the shoreline of Big Cormorant Lake. In 2016, individual sewage treatment systems on 591 parcels surrounding the lake were inventoried and 66 were deemed non-compliant at that time (K. Vareberg, Becker County Zoning, personal communication). Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Big Cormorant Lake's contributing watershed is relatively small as indicated by a watershed-to-lake ratio of 6.2:1. As such, management actions intended to reduce excess nutrient inputs should be relatively targeted and reasonably attainable. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Several AMAs and WPAs exists within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Big Cormorant Lake based on review of non-native species occurrence, stocking activities, angling and other harvest-related activities.

Zebra Mussels (2015), Common Carp, and Chinese Mystery Snails are present within Big Cormorant Lake. Direct competition with the native fish community by Chinese Mystery Snails is unlikely. Any potential effects of Common Carp and Zebra Mussels have not been evaluated or documented; however, recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data).

Historically, Big Cormorant Lake had been stocked with Black Crappie, Lake Trout, Largemouth Bass, Northern Pike, Smallmouth Bass, sunfish, and Walleye. MNDNR Fisheries has not stocked any fish into the lake since 1985, as described in the 2016 lake management plan (MNDNR, unpublished data).

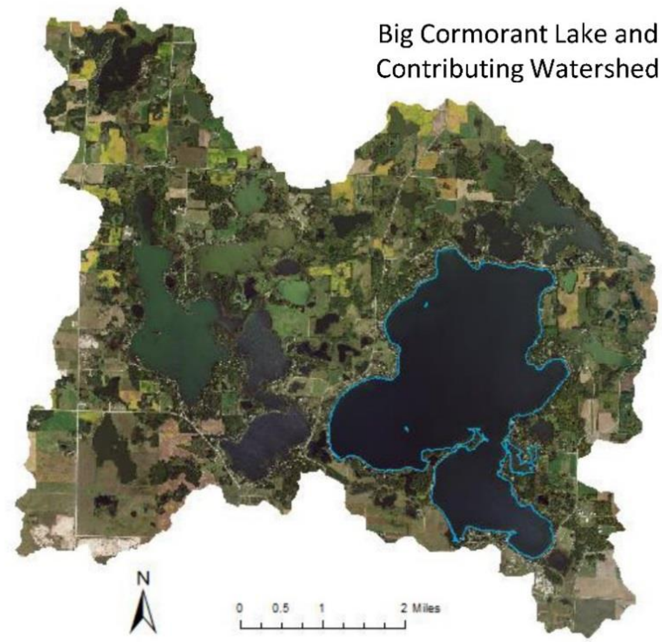
Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest have not been quantified for Big Cormorant Lake; therefore, no data exists with which to evaluate the effects of angling on fish community composition. 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; however, a decreasing trend in Walleyes and questionable year class success over multiple years has led to additional sampling to determine the status of the Walleye population. Commercial harvest, primarily of bullheads but including Common Carp, Bigmouth Buffalo, Bowfin, Burbot, and White Sucker, also occurred between 1946 and the present, but this has likely had little effect on current fish community structure.

Figure 39. Big Cormorant Lake (03-0576-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Big Cormorant Lake (03-0576-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 41, 46 (4 points below, 1 point above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Brook Stickleback, Hornyhead Chub, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Mimic Shiner, Northern Pike, Pugnose Shiner, Pumpkinseed, Rock Bass, Smallmouth Bass, Spottail Shiner, Walleye, Weed Shiner, Yellow Perch
  - Other species that have previously been sampled: Burbot
- **Candidate Causes:**
  - Physical habitat alteration: very high dock density of 34.2 docks per mile of shoreline, low lakewide Score the Shore (StS) of 67, Zebra Mussels, Common Carp, and Chinese Mystery Snails present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
  - Temperature regime changes: estimated 2.0 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: lack of adequate dissolved oxygen at depths containing suitable temperatures during summer months
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 14.5 ppb mean total phosphorus, 40% of contributing watershed classified as unnatural land cover, 11% of individual sewage treatment systems noncompliant in 2016
  - Altered interspecific competition: Zebra Mussels, Common Carp, and Chinese Mystery Snails present, negative effects of stocking activities or harvest unlikely
- **Recommendations:**
  - Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover

Big Cormorant Lake and Contributing Watershed



5.7. Star Lake (DOW 56-0385-00)

Star Lake is 4,454 acres in size and has a maximum depth of 94 feet. The littoral zone of the lake covers 63% of the lake area. Star Lake is scored with FIBI tool 2. Lakes scored with this tool are characterized as generally deep with complex shaped shorelines (i.e., presence of bays, points, and islands) and high species richness (Table 1).

Eutrophication, physical habitat alteration, altered interspecific competition, temperature regime changes, and decreased DO have been identified as inconclusive stressors to aquatic life use in Star Lake and will be evaluated further (Figure 42). A description of available data and current understanding of levels believed to affect fish communities is discussed below.

Biological community

The fish community in Star Lake was sampled using seining and backpack electrofishing during June 2008 and July 2017 and gill netting and trap netting during July 2009 and July 2012. The health of the fish community was evaluated using these data and FIBI tool 2. The FIBI score of 45 in 2017 was equal to the impairment threshold (45) developed for lakes that are similar to Star Lake whereas the FIBI score of 58 in 2008 was above the impairment threshold (Table 3).

During the FIBI surveys, 31 fish species were captured (Table 6). Individual species captured in the nearshore gears varied slightly between surveys (e.g., Mottled Sculpin, Pugnose Shiner, Spottail Shiner, and Tadpole Madtom in 2008 and Brook Stickleback, Fathead Minnow, and Golden Shiner in 2017). The proportion of biomass from tolerant species (i.e., 13% Common Carp) in the trap nets was above the level expected for similar lakes as indicated by the respective FIBI metric. Nine intolerant species, four tolerant species, five small benthic dwelling species, and ten vegetative dwelling species were sampled. Other species sampled in similar lakes within the OTRW that contain healthy fish communities as indicated by the FIBI tool 2 include Cisco, which are also frequently sampled in Star Lake, although not during the 2009 or 2012 gill net surveys. Conversely, species such as Common Carp are generally not sampled in similar lakes that contain healthy fish communities (Table 6). These species have the potential to affect several FIBI metric scores, both positively and negatively.

Because this is the first time utilizing the 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 four additional species have been sampled in Star Lake. Burbot were sampled in MNDNR Fisheries surveys in 1982 and 1988, Shorthead Redhorse were sampled in 1991, and Smallmouth Bass were sampled in 1961, but these species have not been observed in MNDNR surveys since those times (MNDNR 2018c). Cisco were sampled in 10 surveys between 1961–2006 and again in 2018 but were not sampled during the 2009 or 2012 surveys.

Star Lake experienced partial summer kills in one bay in 2014 and 2018 that primarily affected large Walleye and Cisco. Results from pathology lab testing in 2018 were inconclusive but bacterial infection may have been a contributing factor.

Information about select inconclusive causes

Eutrophication

Eutrophication has the potential to occur at a level that would contribute to a vulnerable fish community in Star Lake based on review of watershed disturbance information; however, it is considered an inconclusive stressor based on review of relevant water quality information.

Recent water quality data collected and summarized by MPCA indicates that mean TP is 18.1 ppb (N=40), chlorophyll-a is 5.8 ppb (N=40), and Secchi transparency is 13.3 feet (N=157) in Star Lake. These parameters indicate that excess nutrients may not be a primary cause of stress to the fish community.

Nonetheless, of the 40,248 acres within the contributing watershed, 31.7% is classified as unnatural land cover (i.e., 27.9% agricultural and 3.8% developed). The percentage of unnatural land cover is approaching a threshold identified by MNDNR Fisheries Research that could result in significantly elevated TP levels (Cross and Jacobson 2013).

Approximately 56% of the agricultural land within Star Lake's contributing watershed is cultivated whereas 44% is hay and pasture land. Fourteen feedlots are also located within the contributing watershed (MPCA 2016). Surface runoff from agricultural land and feedlots could contribute excess nutrients into the lake if not properly managed.

Residentially developed land is predominantly located along the shorelines of Star, Big McDonald, West McDonald, and numerous other lakes within Star Lake's contributing watershed. Although data regarding individual sewage treatment system compliance is unavailable for parcels surrounding the lake, records indicate that inspections for compliance had last been completed in 2000 (Rufer and Sherman 2013). Therefore, parcels surrounding the lake could be prioritized for future inspections to ensure compliance and water quality are maintained. Runoff from lawns and discharge from failing individual sewage treatment systems could contribute excess nutrients into the lake if not properly managed.

Additionally, the quantity of land within the contributing watershed was high relative to the size of Star Lake, as indicated by a watershed-to-lake ratio of 9.0:1. The combination of a large contributing watershed and the large percentage of unnatural land cover can contribute large inputs of nutrients into associated lakes and waterways. Although eutrophication is not identified as a primary stressor due to the low TP, low chlorophyll-a, and high Secchi transparency measurements in the lake, the large amount of unnatural land cover within the contributing watershed has the potential to result in inputs of excess nutrients in the future. As such, future development should be carefully planned and best management practices employed to minimize this risk.

Several AMAs, WPAs, and Maplewood State Park exist within the contributing watershed. Undeveloped lands, particularly parcels in public ownership 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.

Physical habitat alteration

Physical habitat alteration has the potential to be occurring at a level that would contribute to a vulnerable fish community in Star Lake based on review of information reflecting riparian lakeshore development, aquatic plant removal, non-native species introduction, water level management, connectivity loss, and sedimentation. However, physical habitat alteration has been identified as an inconclusive stressor.

Riparian lakeshore habitat quality, as indicated by a MNDNR StS score of 76, is moderate within Star Lake and above the statewide average score of 73. Development has had a relatively uniform effect on the shoreland, shoreline, and aquatic habitat components, and indicates that some replacement of trees, shrubs, and natural ground cover with open yards, in addition to removal of some in-lake habitat, has likely occurred. Replacement of riparian vegetation with open lawns oftentimes results in increased nutrient inputs from fertilizer and lawn clippings, reduced buffering capacity, destabilized shoreline, and elimination of future contributions of coarse woody habitat into the lake. One effective way to protect shoreline is through acquisition of AMAs; however, none currently exist on Star Lake to protect vulnerable shoreline from development.

Vegetation removal can also adversely affect the fish community and can occur via several pathways. Landowners can destroy some submersed and floating-leaf vegetation without needing an APM permit, whereas emergent plant removal always requires an APM permit and riparian vegetation removal is governed by county zoning standards. Despite this, compliance checks and enforcement are oftentimes limited. As such, it is difficult to quantify the total amount of habitat loss that has and is presently occurring (whether legal or illegal) around and within Star Lake. According to MPARS, at least 55 properties are, or have been, permitted to remove submersed, emergent, and floating-leaf plants via pesticide application, mechanical removal, or automated aquatic plant control devices to provide riparian access and enhance recreational use, but data for other sources of removal are lacking. Otter Tail County established a program in 2002 to map emergent aquatic vegetation, and a survey was completed on the lake that documented 1,255 acres of floating-leaf and emergent vegetation. A 2016 MNDNR survey has documented 1,566 acres of floating-leaf and emergent vegetation. Anecdotal information about potential plant removal activities (and other habitat alterations such as addition of sand blankets or rip-rap) within a lake can also be inferred from dock counts, and a review from 2016 Google imagery indicates that approximately 365 docks (9.5 docks per mile of shoreline) were present on the lake at that time. Densities exceeding 16–24 docks per mile have been linked to changes in fish community composition (Dustin and Vondracek 2017). Although aquatic plant removal has likely contributed to some physical habitat loss within the lake, significant changes to the fish community are unlikely based on the dock density estimate and the large area of intact floating-leaf and emergent vegetation.

Common Carp, Chinese Mystery Snails, and Purple Loosestrife, three non-native species are present in Star Lake. Any potential effects of these species on the physical habitat within the lake have not been evaluated or documented; however, recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data).

The water level in Star Lake is unregulated (i.e., no water control structure) and has varied by 3.8 feet between 1948–2019 (MNDNR, unpublished data). Within the contributing watershed, one bridge and four culverts have been documented in the MDOT Bridge and Culvert Inventory and the MNDNR Culvert Inventory. Not all crossings or culverts have been evaluated within the contributing watershed; however, culverts at two crossings (i.e., State Highway 108 and 410th Street) have been identified as potential barriers to fish passage (A. Hillman, MNDNR, unpublished data). Several crossings also occur downstream of the outlet, but they have not been identified as potential barriers to fish passage (A. Hillman, MNDNR, unpublished data). Conversely, a dam is located at the outlet of Dead Lake, which ultimately connects Star and Dead lakes to Walker Lake, Otter Tail Lake, and the Otter Tail River. Potential effects to aquatic life within the lake as a result of the dam are uncertain; however, future investigation may be warranted to restore and/or maintain connectivity to the downstream watershed. If the dam or other crossings are determined to act as significant barriers, actions should be considered to restore connectivity.

Altered interspecific competition

Altered interspecific competition has the potential to be occurring at a level that would contribute to a vulnerable fish community in Star Lake based on review of non-native species occurrence, stocking activities, angling, and other harvest-related activities.

Common Carp, Chinese Mystery Snails, and Purple Loosestrife are present within Star Lake. Direct competition with the native fish community by Chinese Mystery Snails and Purple Loosestrife is unlikely. Any potential effects of Common Carp have not been evaluated or documented; however, recent surveys indicate that Common Carp are sampled at a lower rate than in other lakes in the same lake class (MNDNR, unpublished data).

Historically, Star Lake had been stocked with crappies, Largemouth Bass, Northern Pike, sunfish, and Walleye. MNDNR Fisheries currently stocks Walleye fry at a rate of 1,000 per littoral acre in even years, as described in the 2015 lake management plan (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.

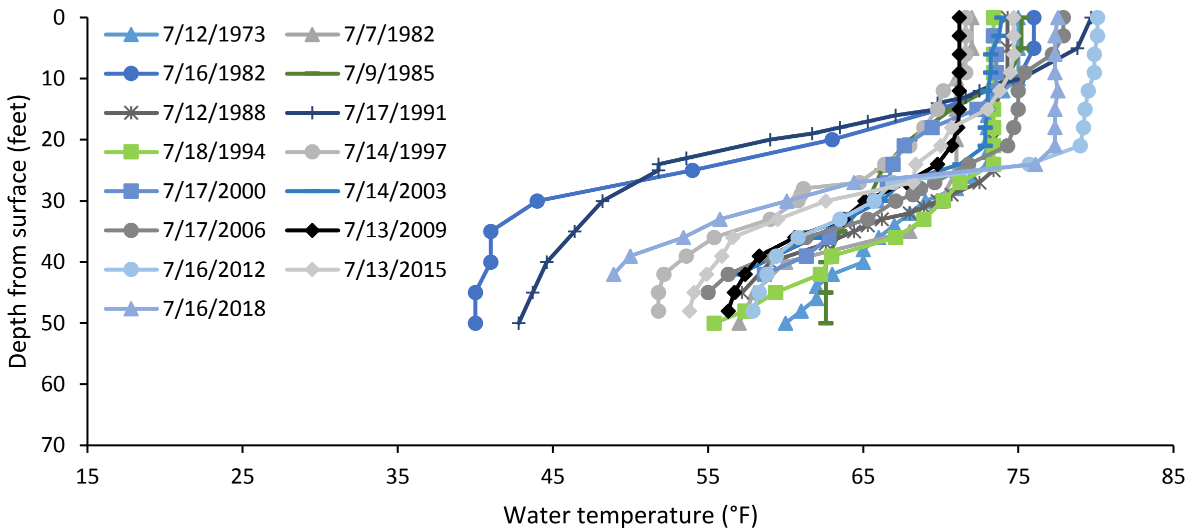
Relative abundances of adult Walleye and Yellow Perch in Star Lake have been variable and both are currently within the lake class inner quartile range (MNDNR, unpublished data). The average relative abundance of Yellow Perch, a primary forage item for Walleye, would suggest that the fish community has not shifted towards being dominated by Walleye as a result of stocking.

Angling and other harvest-related activities also have potential to alter interspecific competition but are unlikely stressors. Angler effort and harvest were quantified during one creel survey conducted in 1987 (Kavanaugh 1988); however, no recent creel surveys have been conducted to compare with the 1987 results. Results during the 1987 survey indicated that fishing pressure and harvest were higher on Star Lake than other Otter Tail County lakes of similar size at that time. An experimental regulation was also initiated in 2005 in an attempt to maintain or improve quality size structure of Bluegill. The regulation was changed to a special regulation in 2015. The creel survey results and special regulation may reflect some concern about angler harvest and its effect on fish community composition through altered interspecific competition. Other relevant activities include annual commercial harvest, primarily of bullheads but also including Bowfin, Burbot, and suckers, that occurs nearly on an annual basis and Cisco sport netting that remains open seasonally.

Temperature regime changes

Temperature regime changes have the potential to be occurring at a level that would contribute to a vulnerable fish community in Star Lake; however, this has been identified as an inconclusive stressor because one coldwater species that would be strongly affected by this stressor was sampled during the FIBI surveys and temperature and oxygen profile data are not available for the month of August, when coldwater habitat is generally most limited in stratified lakes. Modeling indicates that the mean annual air temperature and corresponding water temperature for the lake may have increased by an average of 1.9 °F over the last century as a result of climate change, which is approximately 0.6 °F warmer than for other lakes in the state (Jacobson et al. 2017). July water temperature profiles (measured at predetermined depth intervals from surface to bottom of the lake) have also been collected intermittently during MNDNR sampling between 1973 and 2018 to evaluate habitat for coldwater species (Figure 40). Two coldwater species that would positively influence the FIBI score have been documented in Star Lake. Cisco have been sampled at varying levels whereas Burbot have not been sampled in recent surveys. Despite this, temperature and oxygen conditions in the lake may not be favorable for either species during the summer months, when coldwater habitat is generally most limited. The absence of Burbot from recent surveys could be influenced by the combination of an increase in summer water temperatures and a lack of adequate oxygen at depths containing suitable temperatures, although this would be better evaluated with profiles collected in August. An alternative explanation for their absence could be that Burbot are not frequently sampled with traditional gears. Regardless, consideration should be given to collect future temperature and oxygen profiles in August to better evaluate coldwater habitat availability in Star Lake.

Figure 40. July water temperature (°F) by depth within Star Lake (DOW 56-0385-00).



Decreased dissolved oxygen

Decreased DO has the potential to be contributing to a vulnerable fish community in Star Lake; however, it has been identified as an inconclusive stressor because temperature and oxygen profile data are not available for the month of August, when coldwater habitat is generally most limited in stratified lakes. A review of DO profile data indicates that depths to approximately 16 to 49 feet contained adequate concentrations of DO (i.e., greater than 3 ppm) during the month of July (Figure 41). Water temperatures at these depths were generally within the preferred range of coldwater species such as Burbot and Cisco; however, profiles taken during the month of August would better inform conditions during the most stressful period of the summer for coldwater species. The decrease in oxygen at deeper depths even during the month of July indicate that limited coldwater habitat might be available during months like August, when water temperatures at depth are typically warmest. The low levels of oxygen at deeper depths could be influenced by excess nutrients entering the lake and subsequent decomposition of the resulting organic matter.

Figure 41. July dissolved oxygen concentration (ppm) by depth within Star Lake (DOW 56-0385-00).

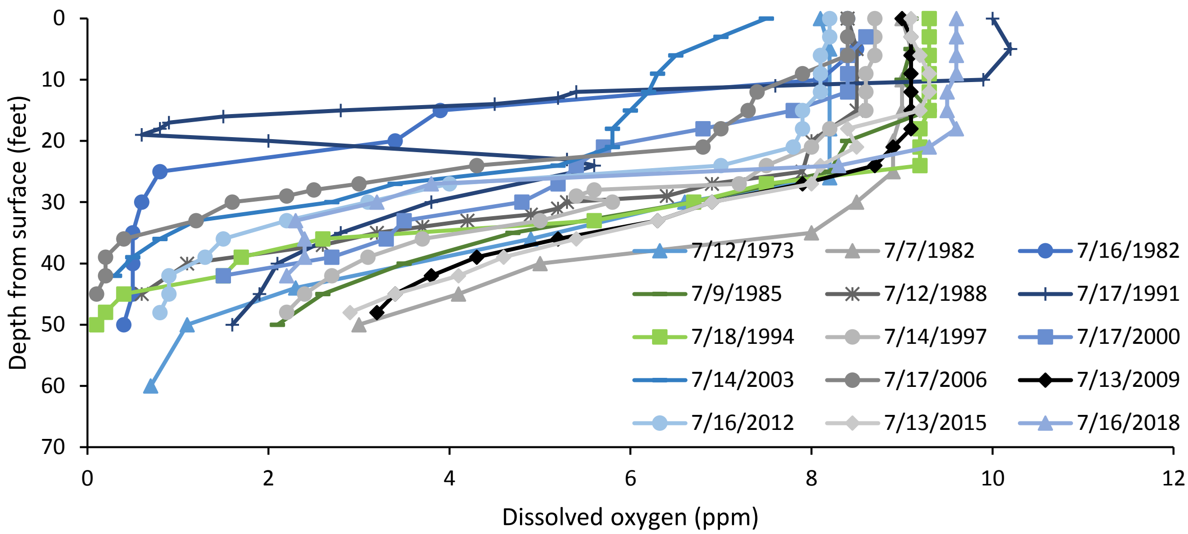
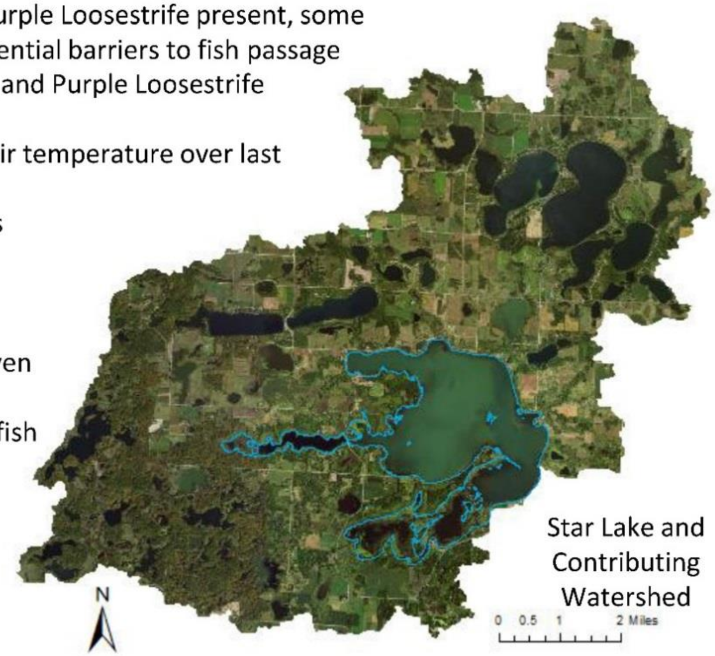


Figure 42. Star Lake (56-0385-00) fish community and stressors; based on fish index of biological integrity (FIBI) results.

Star Lake (56-0385-00) Fish Community and Stressors; Based on Fish Index of Biological Integrity (FIBI) Results

- **Fish Community:**
  - FIBI scores: 58, 45 (13, 0 points above impairment threshold for similar lakes)
  - Species sampled that can negatively affect the FIBI score: Black Bullhead, Bluntnose Minnow, Brown Bullhead, Common Carp, Fathead Minnow, Green Sunfish, White Sucker, Yellow Bullhead
  - Species sampled that positively affect the FIBI score: Banded Killifish, Black Crappie, Blackchin Shiner, Blacknose Shiner, Bluegill, Bowfin, Brook Stickleback, Central Mudminnow, Golden Shiner, Iowa Darter, Johnny Darter, Largemouth Bass, Logperch, Mimic Shiner, Mottled Sculpin, Northern Pike, Pugnose Shiner, Pumpkinseed, Rock Bass, Spottail Shiner, Tadpole Madtom, Walleye, Yellow Perch
  - Other species that have previously been sampled: Burbot, Cisco, Shorthead Redhorse, Smallmouth Bass
- **Inconclusive Causes:**
  - Eutrophication (excess nutrients): 18.1 ppb mean total phosphorus, 32% of contributing watershed classified as unnatural land cover
  - Physical habitat alteration: moderate dock density of 9.5 docks per mile of shoreline, moderate lakewide Score the Shore (StS) of 76, Common Carp, Chinese Mystery Snails, and Purple Loosestrife present, some permitted aquatic plant removal activity, several crossings may act as potential barriers to fish passage
  - Altered interspecific competition: Common Carp, Chinese Mystery Snails, and Purple Loosestrife present, negative effects of stocking activities or harvest unlikely
  - Temperature regime changes: estimated 1.9 °F increase in mean annual air temperature over last century
  - Decreased dissolved oxygen: adequate dissolved oxygen at limited depths containing suitable temperatures during summer months
- **Recommendations:**
  - No candidate cause identified
  - Use best management practices to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover
  - Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted



6. Conclusions and recommendations

Conclusions

Tables 11 and 12 present a summary of the stressors associated with the biologically impaired and vulnerable lakes in the OTRW. Eutrophication (excess nutrients) is adversely affecting the fish communities in Little Cormorant, Upper Cormorant, Walker, Fish, and Sallie lakes. Many of these lakes contain relatively high levels of nutrients such as TP (i.e., greater than approximately 30 ppb) and are located in watersheds with high land use disturbance (i.e., greater than 40%). Other biologically impaired OTRW lakes are located in watersheds that contain relatively high land use disturbance, but eutrophication has been listed an inconclusive cause because nutrient levels are relatively low, although this may not have been the case historically.

Physical habitat alterations are adversely affecting the fish communities in Middle Cormorant, Little McDonald, Paul, Big McDonald, Jewett, Cotton, Sallie, and Big Cormorant lakes. Shoreline development on these lakes is relatively high and has resulted in the loss of both riparian vegetation and native floating-leaf and emergent plant stands that serve as important habitat for fish and other organisms. Additionally, several of these lakes are dammed or are located in watersheds with connectivity concerns, such as culverts or crossings that potentially restrict fish passage. Other biologically impaired OTRW lakes are located in watersheds with connectivity concerns, but physical habitat alteration has been listed an inconclusive cause because shoreline development remains relatively low. Several lakes (i.e., Eagle, Little Cormorant, Little McDonald, Paul, West Silent, and Jewett) 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 the lake's FIBI scores.

Altered interspecific competition was determined to be an inconclusive cause for all lakes that contained non-native species that have the potential to affect fish communities at high densities (e.g., Common Carp and Zebra Mussels). Many of these lakes contained relatively low densities of the non-native species in recent surveys or lacked data regarding densities.

Temperature regime changes are adversely affecting the fish communities in Walker, Big McDonald, Acorn, and Big Cormorant lakes. Decreased DO is adversely affecting the fish communities in Walker, Big McDonald, Acorn, and Big Cormorant lakes. These lakes historically contained at least one coldwater species and currently contain relatively poor coldwater habitat (i.e., temperature and DO) during the summer months.

No candidate causes were identified for several impaired and vulnerable lakes (i.e., Eagle, Anna, West Silent, Toad, Little Toad, and Star lakes). Despite this, several inconclusive causes could simultaneously and cumulatively be affecting the fish communities in these lakes. Other uncommon stressors that were not evaluated in this report, in addition to stressors that may have occurred in the past but are not presently occurring, could also be affecting the fish communities in these lakes. Finally, several of these lakes are relatively isolated (i.e., they lack a significant inlet and outlet) and this could naturally affect fish species richness or limit recolonization of sensitive species if stressors have occurred in the past but have been adequately addressed since that time.

Table 11. Summary of the stressors associated with the biologically impaired lakes in the OTRW.

		Candidate causes[1]				
Lake Name	**DOW**	**Eutrophication (excess nutrients)**	**Physical habitat alteration**	**Altered interspecific competition**	**Temperature regime changes**	**Decreased dissolved oxygen**
Eagle	**03-0265-00**	0	-	-	NE	NE
Little Cormorant	**03-0506-00**	+	0	-	NE	NE
Upper Cormorant	**03-0588-00**	+	0	0	NE	NE
Middle Cormorant	**03-0602-00**	0	+	0	NE	NE
Walker	**56-0310-00**	+	0	0	+	+
Little McDonald	**56-0328-00**	0	+	0	-	-
Paul	**56-0335-00**	0	+	0	NE	NE
Big McDonald	**56-0386-01**	0	+	0	+	+
Anna	**56-0448-00**	0	0	0	NE	NE
West Silent	**56-0519-00**	-	0	-	NE	NE
Fish	**56-0684-00**	+	0	0	NE	NE
Jewett	**56-0877-00**	0	+	-	0	0

[1] "+" supports the case for the candidate cause as a stressor, "-" refutes the case for the candidate cause as a stressor, "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor, "NE" indicates that the candidate cause was not evaluated as a stressor because no coldwater species have been documented in the lake.

Table 12. Summary of the stressors associated with the biologically vulnerable lakes in the OTRW.

		Candidate causes[1]				
Lake Name	**DOW**	**Eutrophication (excess nutrients)**	**Physical habitat alteration**	**Altered interspecific competition**	**Temperature regime changes**	**Decreased dissolved oxygen**
Toad	**03-0107-00**	-	0	0	0	-
Little Toad	**03-0189-00**	0	0	0	0	0
Acorn	**03-0258-00**	0	-	0	+	+
Cotton	**03-0286-00**	-	+	-	0	-
Sallie	**03-0359-00**	+	+	0	0	0
Big Cormorant	**03-0576-00**	0	+	0	+	+
Star	**56-0385-00**	0	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, "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor, "NE" indicates that the candidate cause was not evaluated as a stressor because no coldwater species have been documented in the lake.

Recommendations

The recommended actions listed below will help to reduce the influence or better understand the stressors that are limiting the fish communities of the OTRW. Collaboration among agencies, watershed districts, and local government units will be imperative for successful planning and implementation of these recommendations within the OTRW. Several of the many examples of past collaborative successes include multiple nutrient reduction projects led by the Becker County SWCD and Pelican River Watershed District and a dam modification project on Fish Lake led by the Pelican Group of Lakes Improvement District. Both examples involved numerous project, organizational, and funding partners that were critical to their success.

Eutrophication (excess nutrients)

Best management practices should be employed to reduce 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, maintaining riparian buffer zones around lakes, rivers, and ditches, and using grass waterways and constructed wetlands to filter nutrients from surface waters. In residential areas located around biologically impaired or vulnerable lakes, practices may include minimizing application of lawn fertilizer, reestablishing or maintaining shoreline buffer zones, and ensuring individual sewage treatment systems are compliant with state regulations (Minnesota Rules Chapter 7080) and local government ordinances.

Where applicable, recommendations outlined in lake eutrophication TMDLs should also be followed to minimize potential nutrient inputs from surrounding water bodies (e.g., Norway Lake is nutrient impaired and may be contributing nutrients to Anna Lake).

Land acquisition may also be a viable option to protect lakes from eutrophication and other negative effects of development. Undeveloped forested or wetland areas 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.

Physical habitat alteration

Restoration of developed shorelines with natural shoreline buffers should be prioritized when physical habitat alteration has been identified as a candidate cause of stress to a biologically impaired or vulnerable lake. Shoreland owners can significantly improve shoreline habitat by choosing to reestablish or maintain native plants along their property. Natural shorelines provide overhead cover to fish and wildlife species, contribute important coarse woody habitat into the lake, and provide a buffer for nutrient runoff from lawns and impervious surfaces. While shoreline restoration projects vary in scope and size, all can be completed in ways that are visually appealing and that maintain a view of the lake. Once completed, these projects have potential to provide many ecosystem benefits that a more traditional developed shoreline (e.g., mowed lawn and sand beach) could not offer. The MNDNR maintains an interactive Restore Your Shore webpage that provides guidance for shoreland owners and professionals to use in implementing shoreland restoration projects. Protection and restoration of floating-leaf and emergent aquatic vegetation should also be prioritized, especially where aquatic habitat is limited (e.g., Jewett Lake and Lake Sallie). Shoreland owners should be aware of and adhere to current laws that regulate aquatic plant control. MNDNR APM program staff administer theses controls via a permitting system.

Oftentimes lakeshore parcels are privately owned and developed; however, in some situations land acquisition can be a viable option to protect existing natural shoreline and aquatic habitat. One of many successful examples within the OTRW is the acquisition of three AMAs totaling 117 acres that protect emergent and shoreline vegetation on Toad Lake. Future acquisitions aimed at increasing the percentages of protected shoreline and protected watershed area should be a priority where appropriate. For example, if physical habitat alteration resulting from shoreline development has been identified as a candidate cause of stress to the fish community, emphasis could be placed on land acquisition opportunities to protect remaining undeveloped shoreline.

Recommendations related to other physical habitat alteration concerns should be considered where appropriate. Floating-leaf and emergent vegetation mapping surveys should be completed to document existing plant stands in lakes where these data are lacking (i.e., Middle Cormorant, Paul, Anna, Toad, Little Toad, and Cotton lakes). Regular compliance checks by AMP staff would also be beneficial to document and discourage illegal plant removal activities. Upstream and downstream connections should be restored when crossings (i.e., dams, culverts, and bridges) have been identified as barriers to fish passage and unevaluated crossings should be inspected for potential concerns. Non-native species (e.g., Common Carp, Zebra Mussels) should continue to be monitored in lakes where they are present to ensure they do not reach densities that could substantially alter physical habitat in the future. Additionally, efforts to reduce the spread of non-native species, including those that are absent from the OTRW (e.g., Eurasian Watermilfoil), 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 and Zebra Mussels 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.

Historic efforts to reduce densities of Common Carp via trapping and barriers have been controversial and generally unsuccessful within the OTRW (e.g., Big Cormorant Lake). Common Carp typically occur at relatively low densities in OTRW lakes, and thus these efforts may be expensive, may not be very effective, and may also block migrations of native species.

Temperature regime changes

Temperature regime changes in lakes are driven primarily by climate change. Localized efforts to reduce or offset carbon dioxide and other greenhouse gas emissions should be encouraged; however, changes at a much larger scale will also be required to effectively address climate change. At a local scale, efforts to plant and maintain resilient forests to remove carbon dioxide from the atmosphere as well as efforts to reduce energy consumption, increase energy efficiency, and use alternative low-carbon energy sources should be encouraged.

Water temperature also decreases with increasing depth during the summer months, and in some cases, adequate DO is unavailable at depths where temperatures are cold enough to support species such as Cisco and Burbot. Often, DO concentrations at these depths are influenced by the amount of nutrients in a lake. Higher nutrient levels result in increased productivity but also increased decomposition rates, which result in the consumption of oxygen. By reducing nutrient inputs into lakes that have historically supported coldwater communities, cold and well-oxygenated habitat should become more available during the summer months. Practices recommended in the eutrophication (excess nutrients) section should be considered in these cases.

Decreased dissolved oxygen

DO concentrations vary by depth in stratified lakes. As such, if DO concentrations are low at depths that contain cold enough water to support species such as Cisco and Burbot, habitat conditions may not be favorable. Generally, low DO concentrations are influenced by high nutrient levels in lakes. By reducing nutrient inputs into lakes that have historically supported coldwater communities, cold and well-oxygenated habitat should become more available during the summer months. Practices recommended in the eutrophication (excess nutrients) section should be considered in these cases.

References

BSWCD (Becker Soil and Water Conservation District). 2014. Becker County local water management plan. Becker Soil and Water Conservation District, Detroit Lakes, Minnesota. Available: http://www.co.becker.mn.us/dept/soil_water/PDFs/LWMP-02252015.pdf. (March 2019).

BWR (Bayerl Water Resources). 2014. Otter Tail County local water management plan. Bayerl Water Resources, Alexandria, Minnesota. Available: https://ottertailcountymn.us/wp-content/uploads/2018/09/Local-Water-Management-Plan.pdf. (March 2019).

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.

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.

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.

Erickson, M. L. 2005. Creel survey evaluation of experimental Northern Pike regulations on Lake Sallie and Lake Melissa summer 2003 and winter 2003–2004. MNDNR Completion Report Job 702, Detroit Lakes, Minnesota.

Frey, D. G. 1955. Distributional ecology of the cisco, *Coregonus artedii*, in Indiana. Investigations of Indiana Lakes and Streams 4:177–228.

Fullhart, H. G., and J. D. Wolters. 2009. A summer creel survey of Rush and Little McDonald lakes, Otter Tail County, MN, 2008. MNDNR Completion Report Job 810, Fergus Falls, Minnesota.

Jacobson, P. C., H. G. Stefan, and D. L. Pereira. 2010. Coldwater fish oxythermal habitat in Minnesota lakes: influence of total phosphorus, July air temperature, and relative depth. Canadian Journal of Fisheries and Aquatic Sciences 67:2002–2013.

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.

Jacobson, P. C., G. J. A. Hansen, B. J. Bethke, and T. K. Cross. 2017. Disentangling the effects of a century of eutrophication and climate warming on freshwater lake fish assemblages. PLoS ONE 8:e0182667. DOI: 10.1371/journal.pone.0182667.

Kavanaugh, C., and H. Fierstine. 1987. Creel survey of Heilberger, Jewett, Long, Swan, Tonseth and Wall lakes, Otter Tail County, 1986–1987. MNDNR Completion Report Job 51, Fergus Falls, Minnesota.

Kavanaugh, C. 1988. Creel survey of Dead and Star lakes, May 16–September 7, 1987. MNDNR Completion Report Job 83, Fergus Falls, Minnesota.

MDA (Minnesota Department of Agriculture). 2018. What's in my neighborhood? Agricultural interactive mapping. MDA, St. Paul, Minnesota. Available: https://app.gisdata.mn.gov/mda-agchem/. (November 2018).

MNDNR (Minnesota Department of Natural resources). 2018a. Stressors to biological communities in Minnesota's lakes. MNDNR, Brainerd, Minnesota.

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).

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

MPCA. 2016. Shapefile: feedlots in Minnesota. MPCA, St. Paul, Minnesota. Available: https://gisdata.mn.gov/dataset/env-feedlots. (October 2019).

MPCA. 2018a. Minnesota's impaired waters list. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list. (November 2018).

MPCA. 2018b. Shapefile: what's in my neighborhood (WIMN). MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/document/env-my-neighborhood. (November 2018).

MPCA. 2018c. Surface water data. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/surface-water-data. (November 2018).

MPCA. 2018d. Total maximum daily load (TMDL) projects. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/water/total-maximum-daily-load-tmdl-projects. (November 2018).

MPCA. 2018e. Biological monitoring of water in Minnesota. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/water/biological-monitoring-water-minnesota. (November 2018).

MPCA. 2019. Otter Tail River Watershed stressor identification report. MPCA, St. Paul, Minnesota. Available: https://www.pca.state.mn.us/sites/default/files/wq-ws5-09020103a.pdf (September 2019).

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).

Perleberg, D. 2006. Aquatic vegetation of Toad Lake, Becker County, Minnesota (DOW 03-0107-00), August 2004, June 2005, and May 2006. MNDNR, Brainerd, Minnesota. Available: http://files.dnr.state.mn.us/natural_resources/water/lakes/vegetation_reports/03010700.pdf (September 2019).

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.

Rufer, M., and P. Sherman. 2013. Otter Tail County lakes assessment. RMB Environmental Laboratories, Inc., Detroit Lakes, Minnesota. Available: http://www.eotswcd.org/uploads/files/Otter%20Tail%20County%20Lakes%20Assessment.pdf. (March 2019).

Tollefson, D., M. Ribikawskis, and B. VanRyswyk. 2014. Minnesota national lakes assessment: pesticides in Minnesota lakes. MDA, Pesticide and Fertilizer Management, St. Paul, Minnesota.