39503 Minnesota Pollution Control Agency Post-Hearing Comment Period - Lakes Water Quality Standards Rule

Closed Nov 23, 2026 · Discussion · 3 Participants · 1 Topics · 3 Answers · 0 Replies · 0 Votes

3	1	3	0	0
PARTICIPANTS	TOPICS	ANSWERS	REPLIES	VOTES

SUMMARY OF TOPICS

SUBMIT A COMMENT

3 Answers · 0 Replies

Important: All comments will be made available to the public. Please only submit information that you wish to make available publicly. The Court of Administrative Hearings does not edit or delete submissions that include personal information. We reserve the right to remove any comments we deem offensive, intimidating, belligerent, harassing, or bullying, or that contain any other inappropriate or aggressive behavior without prior notification.

Aaron Johnson · Citizen · (Postal Code: unknown) · Nov 16, 2026 9:48 am

0 Votes

Please see the attached technical comments from EPA Region 5.

Katie Izzo · Citizen · (Postal Code: unknown) · Nov 23, 2026 2:09 pm

0 Votes

Good afternoon! Attached are the following documents from the MPCA:

1. Post-hearing Response to Comments

2. New Technical Support Documents:
a. Ecological Classification of Minnesota Lakes
b. Ambient Water Quality Criteria
c. Lake Plant Survey Manual

3. Updated Technical Support Documents:
a. Development of water quality standards to protect coldwater lake habitats in Minnesota—update to SONAR Exhibit S-04
b. Development of a Tiered Aquatic Life Use Framework for Minnesota Lakes—update to SONAR Exhibit S-05
c. Lake Index of Biological Integrity Nearshore Sampling Manual—update to SONAR Exhibit S-08

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Cooper Silburn · Citizen · (Postal Code: unknown) · Nov 23, 2026 3:10 pm

0 Votes

Attached please find the post-hearing comments of MESERB on the proposed Lakes Water Quality Standards rule. MESERB appreciates the opportunity to comment and thanks the MPCA for its work on this matter.

Thank you.

RECEIVED BY CAH
11/16/2026

REGION 5
CHICAGO, IL 60604

November 13, 2026

William Moore, Rules Coordinator
Office of Administrative Hearings
600 North Robert Street
P.O. Box 64620
St. Paul, Minnesota 55164-0620

Dear Mr. Moore:

On August 24, 2026, the EPA received the Minnesota Pollution Control Agency's (MPCA) public notice of its "Proposed Amendments to Rules Governing Water Quality Standards for Lake Aquatic Life and Recreation, Minnesota Rules Chapter 7050; Revisor's ID Number R-04740; Court of Administrative Hearings docket number 23-9003-39503."

The U.S. Environmental Protection Agency reviewed the draft rules and supporting documents posted on MPCA's website. The EPA's comments are enclosed. The EPA discussed these comments with MPCA on October 23, 2026, and submits these comments in the Minnesota Court of Administrative Hearings eComments website consistent with the State's public notice procedures for comments on possible amendments to water quality standards (WQS) rules. These comments do not constitute final Agency action but are provided for consideration as MPCA develops its WQS revisions for adoption and subsequent submittal for EPA review under Section 303(c) of the Clean Water Act.

Thank you for the opportunity to comment on MPCA's amended use designation rules. If you have any questions, please contact Diane Tancl of my staff at Tancl.Diane@epa.gov or (312) 886-4188.

Sincerely,

11/13/2026

X

for David Pfeifer, Manager
Wetlands and Watersheds Branch
Signed by: TIMOTHY ELKINS

Enclosure

cc: Will Bouchard, MPCA (electronic)
Katie Izzo, MPCA (electronic)

Enclosure – The EPA's Comments on Minnesota's "Proposed Amendments to Rules Governing Water Quality Standards for Lake Aquatic Life and Recreation, Minnesota Rules Chapter 7050; Revisor's ID Number R-04740; Court of Administrative Hearings docket number 23-9003-39503"

Comments Regarding the Draft Proposed Rule Language

Comment 1. Applicability of biological criteria

The draft rule would incorporate the proposed biological criteria for lakes into the tables contained in subparts 2d, 3d and 4d of Minn. R. 7050.0222. There appears to be typographical errors in Subp. 3d and Subp. 4d, as the draft rule language in those subparts reference Class 2A instead of classes 2Bd and 2B, respectively.

Comment 2. Confirmation of WID for West Crab Lake

Please confirm the water body identification code (WID) for West Crab Lake and Crab Lake. The proposed "Use Designation Tables for Lakes" (Exhibit S10 to the Statement of Need and Reasonableness (SONAR)) lists the WID for West Crab Lake as 69-0297-00 and the WID for Crab Lake as 69-0220-00. However, the existing rule language lists two different WIDs for West Crab Lake. Minn. R. 7050.0470, Subp. 2(B)(29) lists the WID for Crab Lake as 69-0220-00 and the WID for West Crab Lake as 69-0297-00, but Minn. R. 7050.0470, Subp. 2(B)(180) lists the WID for West Crab Lake as 69-0220-00.

Comment 3. Definition of lake types for biological criteria

The proposed rules would establish biological criteria for lakes in tables at Minn. R. 7050.0222, subps. 2d, 3d and 4d. Those tables would apply the biological criteria based on water body type (e.g., "Deep, complex lakes", "Deep, moderately complex lakes", "Moderately deep lakes", and "Shallow lakes"). The draft rule at Minn. R. 7050.0150, Subp. 4 includes a definition for "shallow lake," but the draft rules do not define the other waterbody types used in the biological criteria tables, such as "deep", "complex", "moderately deep", or "moderately complex." The EPA's understanding is that the biological criteria are intended to be applied based on the water body groups described in the document "Development of fish-based indices of biological integrity for Minnesota lakes" (Bacigalupi et al. 2021[1]), which is incorporated by reference in the draft rule at Minn. R. 7050.0222, subps. 2c, 3c, and 4c. However, that document does not use the same terms for lake types as those used in the draft rule. Therefore, it is unclear how MPCA or others implementing the criteria would determine which biological criterion applies to a specific lake. To provide clarity on how the biological criteria will apply, MPCA could either add definitions of the water body types to the proposed rules or more explicitly link the descriptions of the waterbody types in Minn. R. 7050.0222 to the groups in Bacigalupi et al. 2021.

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

Comment 4. Averaging period for oxythermal habitat criteria

In Subp. 2 of the draft rule Minn. R. 7050.0222, the proposed criterion for oxythermal habitat (temperature at a dissolved oxygen concentration of 3 mg/L or T_{DO3}) is "an average T_{DO3} … sufficient to support coldwater fish species." The document "Development of water quality standards to protect coldwater lake habitats in Minnesota" (Exhibit S4, hereafter referred to as the Coldwater TSD), indicates that MPCA intends to assess the oxythermal habitat criterion based on a 10-year average, but Subp. 2 does not specify the averaging period or duration of the criterion. Not specifying the averaging period or duration will make the criteria difficult to interpret and implement. This can be avoided by providing additional details as to how the oxythermal habitat standard is to be implemented as a spatial and temporal average and how the averaging period or duration relate to protection of coldwater fish. For example, MPCA could provide additional information in the rule as to how many years of data should be included in the averaging period.

<u>Comments Regarding Proposed Site-Specific Criteria</u>

Comment 5. Documentation presented to support site specific criteria

As discussed in the Coldwater TSD, the technical basis for the proposed site-specific criteria is that these lakes support healthy communities of coldwater fish despite oxythermal conditions in these lakes not meeting one or more of the proposed statewide oxythermal criteria. For these lakes, MPCA has proposed setting site-specific criteria at the current average T_{DO3}, total phosphorus and/or chlorophyll-a conditions in these waters. The available data for some lakes for which MPCA is proposing draft site-specific standards appear to show declining cisco populations (e.g., Sauk (WID 77-0150-02), Koronis (WID 73-0200-02), and Big Birch (WID 77-0084-01 and 02). For other lakes, the available data on coldwater fish populations appear similar to data from lakes in Appendix C of the Coldwater TSD where MPCA determined that coldwater fish populations are declining and determined that site-specific criteria would not be appropriate (e.g., Dam Lake, WID 01-0096-00). Additional explanation of MPCA's decision-making would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).

The data presented in Appendix C of the Coldwater TSD for some of the lakes with proposed site-specific oxythermal criteria (e.g., Fish Trap, WID 49-0137-00, and Farm Island, WID 01-0159-00), appear to show low cisco catch rates or declining populations in these lakes. For these lakes, the Coldwater TSD indicates that MPCA determined site-specific criteria are appropriate because the low catch rate or population decline is due to factors other than elevated T_{DO3}; however, the Coldwater TSD does not provide MPCA's basis for this conclusion. Additional explanation of MPCA's decision-making would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).

Comment 6. Documentation of technical basis for proposed site-specific criteria for Jessie Lake

MPCA proposes site-specific T_{DO3} and total phosphorus criteria for Jessie Lake (WID 31-0786-00) because this lake may not be strongly dimictic and, thus, oxythermal conditions likely differ from other coldwater fisheries lakes. Data presented in Appendix C of the Coldwater TSD appear to show a declining trend in cisco populations and recreation suitability scores at Jessie Lake indicated

non-attainment of recreation goals greater than 11% of the time. Because the available data suggest that the lake may not be supporting the coldwater aquatic life and recreation goals, MPCA set the proposed site-specific criteria for Jessie Lake "slightly below the current conditions." Additional explanation of MPCA's decision-making regarding the selection of the draft site-specific T_{DO3} criterion of 22.0°C and the site-specific total phosphorus criterion of 45 µg/L would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).

Comment 7. Site-specific criteria for lakes with limited data

MPCA proposes site-specific T_{DO3}, total phosphorus and chlorophyll-a criteria for Lake Itasca (WID 15-0016-00). Appendix C of the Coldwater TSD indicates that data for total phosphorus and chlorophyll-a are available from only two summer means, both of which appear to be from before 2010. Additional information about how MPCA evaluated the available data for this lake in developing the site-specific criteria would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).

Comments Regarding Lake Tiered Aquatic Life Uses (TALU) and Coldwater Habitat Use Designations

Comment 8. Documentation of naturally occurring coldwater fisheries

Twenty-five lakes are proposed to be re-designated from Class 2A to Class 2Bdg. According to Appendix C of the Coldwater TSD, the basis for these re-designations is that these lakes were originally designated as Class 2A because they were managed for trout and included on the Minnesota Department of Natural Resources' (MNDNR's) trout lakes list but are no longer managed for trout or included on MNDNR's trout lakes list. Based on the descriptions in Appendix C, it appears that MNDNR's designation decisions do not consider other coldwater fish, such as cisco or lake whitefish. The additional information listed below and identified for specific lakes in Table 1, would assist MPCA in documenting that it has met requirements under 40 CFR 131.5(a)(1).

- The Coldwater TSD states that, for most lakes removed from the trout lakes list, trout were only present in those lakes because of trout stocking. However, it is not clear that MNDNR's decisions regarding the trout lakes list consider other coldwater fish species and the Coldwater TSD acknowledges that there are a small number of lakes on the trout lakes list where the water body may support trout naturally. For some of these lakes, the Coldwater TSD does not discuss the results of any fisheries surveys conducted on these lakes. For others, the Coldwater TSD includes information about fisheries surveys but it does not discuss all the relevant coldwater fish species. For the 25 lakes proposed to be re-designated as Class 2B or Class 2Bd, additional information about whether these lakes support coldwater fish other than stream trout and are expected to be part of the subset that naturally support stream trout would help support the use change. For example, MPCA could provide additional information about whether any fisheries surveys conducted on these lakes documented the presence of coldwater fish species.

- For several of the lakes proposed to be re-designated from Class 2A to Class 2Bdg, the available information in Appendix C in the Coldwater TSD indicates that only one survey was conducted or does not specify how many or if surveys were conducted. The Coldwater TSD states that

decisions about whether a lake supports populations of coldwater fish will typically require data from two surveys (e.g., see Figure 27). Information about the number of fisheries surveys conducted on each lake and why the available data are considered sufficient to conclude that coldwater fish are not present in the lake may be helpful in demonstrating that 40 CFR 131.5(a)(1) has been met.

Comment 9. Documentation of trout water status for Normanna Lake

MPCA has proposed to revise the aquatic life use designation of Normanna Lake (WID 69-1383-00) from Class 2A to Class 2B because MNDNR intends to remove this lake from the trout water list. Because MNDNR's proposed removal of this lake from the trout water list is not final, it is possible that data will be presented to MNDNR that would lead to MNDNR maintaining the trout lake designation for Normanna Lake. The EPA encourages MPCA to verify that it has reviewed all available data before finalizing the proposed use designation for this lake.

Table 1. Lakes proposed to be re-designated from Class 2A to Class 2Bdg for which additional information to support the proposed re-designation may be helpful in demonstrating that 40 CFR 131.10 was met. An "X" indicates that the statement in the column header applies to that specific lake. The abbreviation LAT = lake trout, LKW = lake whitefish, SRT = stream trout, TLC = cisco/tullibee/lake herring.

Lake Name	WID	No Reported MNDNR Fisheries Survey	One Reported MNDNR Fisheries Survey	Number of Coldwater Fish Not Stated	Species Not Discussed
Cone, Upper Lake	16-0412-00			X	LKW, SRT, TLC
Devilfish Lake	16-0227-00			X	LKW, SRT, TLC
Hungry Jack Lake	16-0227-00			X	LKW, SRT, TLC
Lizz Lake	16-0199-00	X		X	LAT, LKW, SRT, TLC
Mulligan Lake	16-0389-00	X		X	LAT, LKW, SRT, TLC
Omega (Onega) Lake	16-0353-00	X		X	LAT, LKW, SRT, TLC
Otto, South Lake	16-0323-00	X		X	LKW, SRT, TLC
Vista Lake	16-0224-00			X	LKW, SRT, TLC
Wanihigan Lake	16-0349-00	X		X	LKW, SRT, TLC
Normanna Lake	69-1383-00	X		X	LAT, LKW, SRT, TLC

Lake Name	WID	No Reported MNDNR Fisheries Survey	One Reported MNDNR Fisheries Survey	Number of Coldwater Fish Not Stated	Species Not Discussed
Unnamed – 8 MI N of DULUTH	69-0122-00	X		X	LAT, LKW, SRT, TLC
Mirror Lake	69-0234-00	X		X	LAT, LKW, SRT, TLC
Agamok	38-0011-00	X		X	LKW, SRT, TLC
Arkose	38-0382-00		X		
Big Ruby Lake	69-0333-00	X		X	LAT, LKW, SRT, TLC
Brandt	16-0600-00		X		
Crab Lake	16-0357-00			X	LKW, SRT
Marble Lake	38-0109-00	X		X	LKW, SRT, TLC
Mora	16-0732-00		X	X	LKW, SRT, TLC
Tarry Lake	16-0731-00	X		X	LKW, SRT, TLC
Virgin	16-0719-00		X	X	LKW, SRT, TLC
West Crab	69-0297-00	X		X	LAT, LKW, SRT, TLC
East Twin Lake	03-0362-00	X		X	LAT, LKW, SRT, TLC
Willard Lake	11-0564-00	X		X	LAT, LKW, SRT, TLC

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Commenter name (& affiliation if known)	Rule part	Topic	Comment (summarized if marked with *)	MPCA response	Discussed on SONAR page or supporting doc	Comment type	Exhibit #
Ryann Geldner	Minn. R. 7050.0222; Minn. R. 7050.0150	General support	* Support for the proposed amendments because they will refine and strengthen protections for lakes	Attachment 2, Section A	Hearing Exhibit D, SONAR [pp. 13-16, 32-40]	pre-hearing eComment	I-1.1
Ryann Geldner	Minn. R. 7050.0227	Class 7 use designation	...request that MPCA remove Class 7 entirely and classify all waters under protective Classes 1–6.	Attachment 2, Section B	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Ryann Geldner	Minn. R. 7050.0222	Implementation of additional protections for lakes	**Incorporate macroinvertebrate monitoring into lake assessments.** Macroinvertebrates are foundational to lake food webs and are sensitive indicators of eutrophication, sediment oxygen depletion, and chemical disturbance. Including benthic macroinvertebrate metrics would greatly improve biological condition assessments under TALU.	Attachment 2, Section C.1	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Ryann Geldner	NA	Implementation of additional protections for lakes	**Add protections or scoring incentives for lakes with intact native plant shorelines.** Native littoral vegetation supports fish spawning, amphibians, macroinvertebrates, and water quality. TALU tiers should recognize and reward lakes with high quality shoreline habitat.	Attachment 2, Section C.2	Hearing Exhibit D, SONAR [pp. 40-43]; Perleberg et al. 2025 [pp. 18-32]; SONAR Exhibit S-5 [Appendix A]	pre-hearing eComment	I-1.1
Ryann Geldner	NA	Implementation of additional protections for lakes	**Require ecological monitoring after aquatic herbicide treatments.** Chemical treatments can affect dissolved oxygen, sediment chemistry, macroinvertebrates, and amphibians. Minnesota does not currently require post treatment biological monitoring. Adding this requirement would align lake management with the rule's aquatic life protection goals.	Attachment 2, Section C.3	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Ryann Geldner	NA	Implementation of additional protections for lakes	**Improve oversight of cumulative chemical applications.** A single lake can receive multiple herbicide permits from individuals, associations, and contractors. MPCA should track cumulative chemical load to ensure aquatic life standards are not unintentionally compromised.	Attachment 2, Section C.3	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Ryann Geldner	NA	Implementation of additional protections for lakes	**Create a public, searchable database of all aquatic herbicide permits and quantities.** Transparency is essential for public trust and scientific evaluation. A centralized database would allow citizens, researchers, and local governments to understand how much chemical treatment is occurring and where.	Attachment 2, Section C.3	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Ryann Geldner	Minn. R. 7050.0222	Implementation of additional protections for lakes	**Ensure TALU does not unintentionally reduce protection for modified or degraded lakes.** TALU should continue to encourage restoration and improvement. Lakes with intact native plant shorelines should receive higher protection, and lakes with degraded littoral zones should not be permanently assigned lower expectations.	Attachment 2, Section C.4	Hearing Exhibit D, SONAR [pp. 40-43]	pre-hearing eComment	I-1.1
Kathy DonCarlos, Northwern Waters Land Trust—Land Conservation Program	Minn. R. 7050.0222; Minn. R. 7050.0150	General support	* Support for the proposed amendments because they will refine and strengthen protections for lakes	Attachment 2, Section A	Hearing Exhibit D, SONAR [pp. 13-16, 32-40]	pre-hearing mail/fax	I-1.2
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	...the Red River Basin (RRB) is hydrologically, geographically, and biologically different from many other regions of Minnesota. These differences must be fully reflected in both the final rules and their subsequent implementation. It also amplifies the need for engaging local experts in processes and procedures associated with the Clean Water Act implementation. The RRWMB is particularly concerned that standards, biological criteria, lake classifications, reference conditions, and impairment methodologies developed on a statewide basis could produce unintended consequences when applied to the naturally shallow, highly variable, wetland influenced, low gradient waters of Northwest Minnesota. Although it is unlikely these rule changes will add restrictions relative to construction of WD projects, the RRWMB is opposed to any additional restrictive rules with no basis for the classification changes. Accordingly, the RRWMB requests that MPCA incorporate the following considerations into the final rule and its implementation.	Attachment 2, Section D.1 and D.2	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	The Minnesota portion of the RRB encompasses a remarkably diverse landscape extending from the Lake Agassiz Plain eastward into lake, forest, and wetland dominated portions of Northwest Minnesota. Local WD staff have decades of experience working in these unique conditions. As such, we strongly encourage the State of Minnesota to increase its level of engagement with local stakeholders when making policies, rules, or implementing Clean Water Act activities in the RRB. The proposed rule specifically recognizes 17 HUC-8 watersheds within the Red River of the North Basin. However, these watersheds do not represent a uniform aquatic environment. The RRB is the bed of former Glacial Lake Agassiz and is characterized by extremely low gradients, extensive agricultural drainage, naturally fine soils, high sediment mobility, wetland complexes, shallow water bodies, and highly variable hydrology. Farther east, the basin transitions into landscapes containing numerous natural lakes, forests, wetlands, coldwater resources, and substantially different soils and watershed characteristics. The final rule should expressly recognize that the attainable biological and chemical condition of a water body must be evaluated in the context of its natural watershed, geomorphic, hydrologic, and ecological setting. Again, local practitioners like staff at WD's and Soil and Water Conservation Districts (SWCD) have decades of firsthand boots-on-the-ground experience in addressing this natural variation.	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3

Robert Sip & John Finney, Red River Watershed Management Board	NA	Natural variability	During the 1st cycle of the watershed approach in Minnesota, local expertise had more direct engagement with the MPCA before, during, and after processes like the proposed rules. We strongly encourage the MPCA to reinstitute stronger stakeholder engagement with local stakeholders before, during, and after the implementation of processes like the proposed rule changes. The RRWMB is available to discuss effective strategies for engaging stakeholders within the RRB. For example, it is not uncommon for an intense rainfall event to impact a localized area within a watershed. Typically, local WD and SWCD staff will be aware of these events and familiar with the specific impacts. Without local coordination, it would be difficult for regionally based state agency staff to recognize this type of impact if monitoring towards the proposed rule was scheduled to occur a few days after the event. Local stakeholder coordination could help to resolve this issue. As such, the RRWMB strongly recommends development of a clear and accessible process through which WD's and other affected parties can be collaboratively engaged before, during and after the application of Clean Water Act procedures to waters in the RRB.	Attachment 2, Section D.1 and D.2	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	See Attachment 2, Item D.1, D.2	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**2. Natural Background Conditions Must Be Distinguished from Human Caused Pollution:** Perhaps the most important issue for the RRWMB is the treatment of natural background conditions. Natural watershed characteristics can contribute significant amounts of phosphorus to lakes. The MPCA's analysis acknowledges that natural watershed sources of nutrients can be substantial in RRB. Elevated phosphorus concentration does not necessarily demonstrate anthropogenic pollution, and reduced water transparency does not necessarily demonstrate human caused degradation. Naturally productive shallow lakes, wetland dominated watersheds, peatlands, organic soils, internal nutrient cycling, wind driven sediment resuspension, fish communities, drought, flooding, and natural hydrologic variability can substantially affect observed water quality. Alternatively, the elevated phosphorus concentrations maybe be significantly impacted by human activities such as stormwater, historical direct disposal of sewage, historical creamery waste disposal, historical mortuary waste disposal, historical sawmill waste disposal, or unmanaged water from rural settings. It is just as important as the natural causes to understand the human causes. Before determining that a water body is impaired or requiring additional nutrient reductions, MPCA should demonstrate that the observed condition represents a departure from the reasonably attainable natural condition of that water body. Local knowledge and insights should help inform these decisions. WD's and landowners should not be required to implement costly restoration measures intended to achieve conditions that are naturally unattainable. The RRWMB recommends that the final rule or associated implementation guidance explicitly establish a process for separating: • Natural background loading. • Internal loading and natural nutrient cycling. • Wetland derived nutrients and organic matter. • Naturally occurring turbidity and sediment conditions. • Climate and hydrologic variability. • Anthropogenic pollutant loading.	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**3. Lake Classification Decisions Must Be Transparent and Reviewable:** The proposed framework places increased importance on determining the appropriate lake category, especially in the Lake Agassiz Plain ecoregion that does not have a unique set of Lake Eutrophication Standards (LES) and relies on professional judgment to assign a set of standards based on how the lake compares to lakes in ecoregions with LES. Lake classification can involve depth, littoral area, thermal stratification, fish communities, and other characteristics that some lakes do not fit neatly within established categories. In such cases, professional judgment may be necessary. Professional judgment is necessary in the RRB, and the classification decisions can have significant regulatory consequences. A lake classification determines the appropriate water quality standards, which can in turn determine whether a lake is considered impaired. The Lake Agassiz Plain contains water bodies that may naturally exhibit high nutrient concentrations, turbidity, limited transparency, shallow depths, wetland influence, and other characteristics that could be unusual in recreational lakes elsewhere in Minnesota. The RRWMB therefore recommends that MPCA establish, or continue using, a transparent classification process that: • Identifies the data supporting the classification. • Identifies the criteria used. • Documents the scientific rationale. • Allows consideration of locally collected data. • Provides notice to affected watershed districts and local governments. • Establishes a meaningful process for reviewing or challenging an incorrect classification. Classification should not become an administrative determination that is effectively unreviewable once incorporated into an impairment assessment. But rather, it should include local feedback and insights to help determine the correct classification and application of water quality standards. For mixing type classification, it is important to incorporate temperature and dissolved oxygen profile data, when available. Discissions on mixing classification should go beyond the use of the geometric ratio alone, to ensure the most appropriate standards are applied to the lake. Local flexibility when classifying a lake and applying a standard is important. The Lake Agassiz Plain ecoregion spans 500 miles end-to-end. Applying a single numeric standard to accommodate a wide range of conditions within the same ecoregion can lead to unattainable targets without site-specific considerations. The RRWMB therefore requests that MPCA retains a scientifically defensible mechanism for establishing site-specific expectations for Lake Agassiz Plain waters rather than applying standards developed from substantially different lake populations. MPCA should also clearly explain the methodology that will be used to establish those site-specific standards. Local WD's and other affected local governments should have a meaningful opportunity to review the data, reference conditions, lake classification, and proposed standard before a site-specific determination becomes the basis for an impairment listing or regulatory requirement.	Attachment 2, Section D.2 and D.3	Schupp (1992); SONAR Exhibits S-5 [p. 3, 12-13, 27-50] and S-8 [p. 5]	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**4. Biological Criteria Must Account for Natural Variability:** The RRWMB recognizes the value of biological monitoring. Fish and other biological communities can provide important information about long-term aquatic ecosystem health that may not be apparent from individual chemical samples. However, biological communities are affected by many factors unrelated to conventional pollution. These include drought, flooding, winterkill, natural lake level fluctuations, fish stocking, invasive species, predation, natural barriers, lake connectivity, habitat changes, temperature, dissolved oxygen, and historical conditions. The proposed rules allow biological quality to be evaluated against biological condition models or reference water bodies intended to represent natural conditions for a particular water body type and geographic region. The choice of appropriate reference conditions is therefore extremely important. MPCA should not conclude that an observed biological difference represents anthropogenic impairment unless there is adequate evidence connecting that condition to a human caused stressor. As part of this, reference water bodies should be carefully selected, within geographically relevant proximity and be subject to public feedback. Consistent with previous comments, this should also include a local stakeholder coordination process that engages local stakeholders prior to, during, and after reference conditions are set.	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3

Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222; Minn. R. 7050.0470	Natural variability	**5. Exceptional Use Designations Require Clear Criteria and Local Participation:** The proposed framework establishes exceptional aquatic life classifications, including Class 2Ae, 2Bde, and Class 2Be waters. The RRWMB supports protecting genuinely exceptional aquatic resources. However, an exceptional use designation can have consequences extending beyond the water body itself, particularly if the designation influences antidegradation requirements, watershed planning, land use priorities, permitting, or projects upstream. Accordingly, exceptional use designations should be based on clear and reproducible criteria, adequate monitoring data, consideration of natural variability, and consultation with affected WD's and local governments.	Attachment 2, Section D.2 and D.3	Schupp (1992); SONAR Exhibits S-5 [p. 3, 12-13, 27-50] and S-8 [p. 5]	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**6. Coldwater and Oxythermal Standards Should Reflect Site-Specific Conditions:** The RRWMB recognizes the ecological importance of protecting coldwater fish communities. The MPCA proposes new oxythermal habitat criteria intended to directly measure the suitability of temperature and dissolved oxygen conditions for sensitive coldwater species. These protections may be particularly important in portions of the eastern RRB. However, MPCA should ensure that naturally occurring temperature or dissolved oxygen conditions are not interpreted as anthropogenic impairment without sufficient evidence. Climate trends, lake morphology, groundwater interaction, water levels, seasonal conditions, and natural oxygen dynamics should be considered before regulatory conclusions are reached. The oxythermal standard needs more definition in the rules. The standard states "an average TDO3 sufficient to support coldwater fish species…" Is this the summer average for the lake, the average over the water column at any given time, or the summer average at a specific depth?	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	NA	Economic review	**7. MPCA Should Evaluate the Potential Effect on TMDLs and WRAPS:** A water quality standard does not operate in isolation. Once adopted, standards become part of the framework used to determine whether waters are meeting designated uses. New or revised standards can therefore lead to additional impairment determinations that then have downstream impacts on planning and implementation efforts. Driven by the importance of the downstream impacts of standards, the RRWMB requests that MPCA provide a RRB specific analysis estimating: • The number of Red River Basin water bodies potentially affected by the revised standards. • The number potentially subject to a different impairment determination. • The number potentially receiving exceptional use classifications. • The likely effects on future WRAPS and TMDLs. • Additional monitoring requirements. • Potential implementation costs. • A use attainability analysis for the standards within the region. • Potential costs to local governments and watershed districts. Without this information, it is difficult for affected local governments to understand the full fiscal and operational consequences of the proposed rules.	Hearing Exhibit I-2; Attachment 2, Section E.1	Hearing Exhibit D, SONAR [pp. 49-61]	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	NA	Maintence of multiple benefits	**8. Flood Damage Reduction and Multipurpose Water Management Projects Must Remain Feasible:** Flood damage reduction is an essential public responsibility within the RRB. The exceptionally flat topography of the RRB, historical wetland alterations, extensive drainage infrastructure, severe spring flooding, intense summer rainfall events, and international and interstate drainage characteristics require active water management. The RRWMB and its member WD's have invested substantial resources in projects that reduce flood damage while increasingly incorporating water quality, habitat, erosion control, wetland restoration, and other environmental benefits. The final rules should not unintentionally create barriers to properly designed multipurpose water management projects. Projects involving flood impoundments, diversions, channel restoration, grade control structures, wetland restoration, floodwater storage, drainage improvements, and other hydrologic modifications should be evaluated according to their overall environmental and public benefits. The MPCA should coordinate with WD's early in project development rather than allowing biological or water quality standards to become an obstacle late in permitting.	Hearing Exhibit I-2; Attachment 2, Section F	Hearing Exhibit D, SONAR [p. 38]	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	NA	Natural variability	**9. Climate and Extreme Hydrologic Conditions Must Be Considered:** The RRB experiences extraordinary hydrologic variability. A water body may experience drought, extreme spring runoff, prolonged flooding, intense rainfall, low flow conditions, winterkill, or substantial year-to-year water level fluctuations. These conditions can dramatically alter nutrient concentrations, sediment transport, dissolved oxygen, temperature, biological communities, and water clarity. The proposed standards should therefore be implemented using sufficiently long periods of record and appropriate hydrologic context so that temporary or extreme conditions are not mistaken for permanent anthropogenic degradation. The process by which these decisions are made and incorporated into associated work should be clearly documented and communicated.	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0150, subp. 4	Clarifications and corrections to proposed rule language	**10. Are Shallow Lakes now Excluded From LES on Purpose?** Are LES no longer applied to shallow lakes? The proposed changes to the rules are written, under the definitions and water quality standard, in a way to exclude shallow lakes from the LES.	Hearing Exhibit I-2; Attachment 2, Sections G.1 and H.1	Hearing Exhibit D, SONAR [pp. 23 (footnote 13), 41]; SONAR Exhibit S-3 [pp. 12-13]; Hearing Exhibit C	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Clarifications and corrections to proposed rule language	**11. Are Only Class 2A Lakes Being Assigned Biological Criteria UDraft MN Rules 7050.0222?** Under subpart 3d for Class 2Bd waters (starting on line 43.4) and subpart 4d. for Class 2B waters (starting on line 63.22), there are no biological criteria for Class 2Bd and Class 2B lakes. The biological criteria listed in the tables for Deep, complex lakes; Deep, moderately complex lakes, Moderately deep lakes, and Shallow lakes list either "2Ae" for exceptional or "2Ag" for general under "Class". Why are Class 2Ae and 2Ag lakes listed under Class 2Bd (subp. 3) and Class 2B (subp. 4)? Are all lakes going to be classified as Class 2A for biological criteria? The same biological criterion is used for each class (2A, 2Bd, and 2B), is this correct? We suspect this is a drafting error that should be corrected before the proposed changes are accepted. If it is not a drafting error, can you provide clarity to why Class 2A lakes WQS are listed under Class 2Bd and 2B?	Hearing Exhibit I-2; Attachment 2, Section H.2	Hearing Exhibit C	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**12. Differing Lake Classification System Between Lake Eutrophication Standards and Biological Criteria for Lakes:** Why is the lake classification system under the biological criteria different from the eutrophication standards? The proposed classification system for LES is mixing type (dimictic or polymictic) and ecoregion. The LES of the biological criteria uses Deep, complex lakes; Deep, moderately complex lakes; Moderately deep lakes, and Shallow lakes. Due to the switch of lake type under the classification for LES, would it make sense to use mixing type (dimictic or polymictic) instead of reverting back to the current system of depth type (deep and shallow)? It would result in less confusion. In addition, how are Deep, complex lakes; Deep, moderately complex lakes; Moderately deep lakes classified? What criteria are used to determine a lake's complexity? When and who determines it? This information is not easily accessible, laid out in the supplemental material or found when searched for "complex". The rules can be improved by clearly defining these classifications in the rule to increase the accessibility of information to general readers in understanding the rules.	Attachment 2, Section D.3	Schupp (1992); SONAR Exhibits S-5 [p. 3, 12-13, 27-50] and S-8 [p. 5]	pre-hearing eComment	I-1.3

Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Natural variability	**13. Are Polymictic and Dimictic Determined Solely on Geometric Ratio?** Is geometric ratio, i.e. as the fourth root of lake surface area (m2) divided by maximum depth (m) (A00.25/Zmax, where A0 is lake surface area and Zmax is maximum depth), the sole indictor that is going to be used to for determining mixing type, or is it going to be a starting point and final determination be made during professional judgement? What about lakes with a littoral area of greater than 80%? If a lake has a large littoral area where most of the lake acts like a polymictic lake but has a small deep area with a maximum deep above 15 feet and the geometric ration identifies it as a dimictic lake, would it be still considered a dimictic lake? If profile data is available, will it be used over the geometric ratio? It is important to use all available profile data when determining the mixing state of a lake. This was not clear under the materials provided. Please clarify.	Hearing Exhibit I-2; Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	pre-hearing eComment	I-1.3
Robert Sip & John Finney, Red River Watershed Management Board	Minn. R. 7050.0222	Modified use designation for lakes	**14. Why no "Modified" TALU Class for Lakes?** Unlike streams, there is no "modified" designation for lakes. Are there any future plans to investigate if a "modified" designation may be needed for lakes that historically have not supported a healthy fish and macroinvertebrate community?	Hearing Exhibit I-2; Attachment 2, Section I	(SONAR Exhibit S-5 [p. 6]	pre-hearing eComment	I-1.3
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Request for additional information	Please provide a list of the three NPDES/SDS facilities upstream of proposed exceptional use lakes. [MPCA SONAR, Minn. R. ch. 7050, at 54 (Aug. 2026) (Doc. No. wq-rule4-27d)]	Hearing Exhibit I-2; Attachment 2, Section G.2	NA	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Request for additional information	Please provide a list of the 12 permit holders identified as potentially impacted by the revised eutrophication standards for northern lakes. [See SONAR p. 55]	Hearing Exhibit I-2; Attachment 2, Section G.2	NA	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Request for additional information	Please also provide the list of the 7 lakes identified that would likely be considered assessed as impaired under the proposed northern dimictic standards but not under the existing standards.	Hearing Exhibit I-2; Attachment 2, Section G.2	NA	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Request for additional information	Please provide a list of the 15 wastewater permits located upstream or adjacent to lakes that MPCA determined could become impaired based on the proposed coldwater aquatic life and habitat standards and designations. [See SONAR p. 58]	Hearing Exhibit I-2; Attachment 2, Section G.2	NA	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Economic review	Please confirm that when the agency identified the above-referenced 15 wastewater treatment facilities, MPCA evaluated all new chemical and physical standards that come with the proposed new Class 2A and 1B designations. Specifically, MESERB requests that MPCA confirm whether it evaluated the potential impacts to wastewater facilities that will result from the application of new and more stringent standards for ammonia, nitrate, sulfate, and TDS, in addition to the new eutrophication standards.	Hearing Exhibit I-2; Attachment 2, Section G.2	NA	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.042	Class 1 designation	The SONAR states that the rule is not "a change to any use class other than Class 2." [SONAR at 13 & n.3.] However, in operation, it appears that it is. Under Minn. R. 7050.0420, a Class 2A designation carries Class 1B, and the Agency acknowledges that Class 1B adds standards for sulfate, total dissolved solids, fluoride, nitrate plus nitrite, and several metals. [Minn. R. 7050.0420; SONAR, supra note 1, at 51, 56, 58.] The proposal designates 410 lakes as Class 2A, which then results in many, if not all, of those lakes becoming subject to drinking water standards as well. [SONAR, supra note 1, at 27-28 (Table 5).] Based on our review, it appears that MPCA is proposing to designate these lakes as Class 1 waters (many for the first time) without specifically evaluating or confirming whether the Class 1 designation is appropriate for those Lakes. [SONAR at 13 n.3 ("Class 1 designations are not reviewed as part of the scope of this rule.")] Please confirm whether MPCA has specifically evaluated the appropriateness of the Class 1 designation for the lakes at issue? If not, why?	Hearing Exhibit I-2; Attachment 2, Sections E.2 and J	Hearing Exhibit D, SONAR [p. 57]	pre-hearing eComment	I-1.4

Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.042	Request for additional information	Please provide more information on how many lakes will receive a new Class 1 designation because of the proposed rule amendments.	Hearing Exhibit I-2; Attachment 2, Sections G.2 and J	Hearing Exhibit D, SONAR [pp. 22 (body text and footnote 10), 23 (footnote 13), 27-28, 41]; SONAR Exhibit S-3 [pp. 12-13]; SONAR Exhibit S-4 [p. 3]; State Register, 1 June 2020, Volume 44, Number 49 [p. 1416]; State Register, 26 June 2023, Volume 47, Number 52 [p. 1207]	pre-hearing eComment	I-1.4
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.047	Use classification tables	As part of this rulemaking, beneficial use designations for lakes will be listed in tables incorporated by reference into Minn. R. 7050.0470. We request that MPCA confirm whether it is required to conduct rulemaking before changing or adding waters or new beneficial use designations to waterbodies on the lists incorporated by reference into that rule.	Hearing Exhibit I-2; Attachment 2, Section K	SONAR Exhibit S-10	pre-hearing eComment	I-1.4
Colin Jefferis submitting for Jason Schlender, Great Lakes Indian Fish & Wildlife Commission	Minn. R. 7050.0222; Minn. R. 7050.0150	General support	"The proposed lake eutrophication standards, oxythermal and eutrophication standards for cold water aquatic life uses, and Tiered Aquatic Life Use (TALU) framework are meaningful improvements that address the natural diversity of lakes throughout the Ceded Territories." "Commission staff support the addition of oxythermal and eutrophication habitat standards specific to the requirements of cold water fish species, including cisco, lake whitefish, lake trout, and stream trout. *Support for refined lake eutrophication standards which acknowledge polymictic and dimictic lakes in the North region. "Staff of the Commission support the use of a TALU scale as it is more representative of the diversity of non-human beings throughout the 1854 and 1837 Ceded Territories and creates more stringent criteria for exceptional waters. "	Attachment 2, Section A	Hearing Exhibit D, SONAR [pp. 13-16, 32-40]	pre-hearing eComment	I-1.5
Colin Jefferis submitting for Jason Schlender, Great Lakes Indian Fish & Wildlife Commission	Minn. R. 7050.0222; Minn. R. 7050.0150	General support	Commission staff support the addition of oxythermal and eutrophication habitat standards specific to the requirements of cold water fish species, including cisco, lake whitefish, lake trout, and stream trout [Exhibit SO4 at 2].	Attachment 2, Section A	Hearing Exhibit D, SONAR [pp. 13-16, 32-40]	pre-hearing eComment	I-1.5
Colin Jefferis submitting for Jason Schlender, Great Lakes Indian Fish & Wildlife Commission	Minn. R. 7050.0222	Implementation of additional protections for lakes	...in a technical support document for the draft amendments, the authors write that the criteria of the amendments “do not necessarily reflect optimal conditions for these fish species but rather are minimal conditions for their protection.” [Exhibit SO4 at 36] While these standards do maintain aquatic conditions for species protection as required by MN R 7050.0250 (a), this comment encourages the promulgated standards to reflect the optimal conditions for the growth of non-human being populations. Maintaining the populations of cold water fishes at replacement levels provides no resilience for the species to demographic or environmental disturbance. GLIFWC encourages the state to adopt standards that would allow for cold water fish populations to thrive. Abundant, thriving, genetically diverse populations of cold water fish are more likely to be able to adapt to a changing environment.	Attachment 2, Section C.5	Hearing Exhibit D, SONAR [pp. 34]	pre-hearing eComment	I-1.5
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.042	Class 1 designation	We understand this rulemaking primarily concerns the Class 2 use. As we read Rule 7050.0420, Class 2A waters are also automatically classified as Class 1B, as a drinking water use, and that includes standards for nitrate and sulfate, among others. The SONAR notes that Class 1 designations are outside the scope of this rule. We might be missing something and we just hope that the agency can help us understand how many of the approximately 411 new 2A lakes would become Class 1 for the first time and how it considered whether that use fits those lakes.	Hearing Exhibit I-2; Attachment 2, Section J	Hearing Exhibit D, SONAR [pp. 13-14 (body, footnote 3); p. 22 (body, footnote 9); p. 56]	hearing transcript	M
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.0470	Natural variability	Cisco seem to account for many of the new 2A designations. The technical report does note that there are many lakes that are suitable habitat, but that do not contain Cisco, so we are interested if the agency could walk us through how it confirmed that each of these new lakes would support Cisco specifically.	Attachment 2, Section D.4	SONAR Exhibit S-4 [pp. 51-57, Appendix E]	hearing transcript	M

Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	NA	Economic review	...regarding some impacts to waste water treatment facilities, specifically economic impacts, as we understand it, the agency estimates the probable cost of complying with the rule, and this includes costs to local governments, the SONAR notes that the modeling needed to identify affected facilities wasn't feasible. No specific costs could be determined in this regard, and we're just hoping that the agency could help us understand how it reached the conclusion that the impacts won't be large or widespread without that analysis.	Attachment 2, Section E.3	Hearing Exhibit D, SONAR [pp. 49-61]	hearing transcript	M
Cooper Silburn submitting for Scott Gilbertson, Minnesota Environmental Science and Economic Review Board	Minn. R. 7050.0222	Natural variability	The SONAR seems to anticipate that site-specific standards will ease impacts for many of the new uses for these lakes. In our members' experience, site-specific standards, they do take a significant amount of time and resources, so we are hoping that the agency can share how it envisions the site-specific standard process working for this rulemaking, who would lead it and whether the agency will be spearheading this development or whether that's going to be municipalities.	Attachment 2, Section D.1	Hearing Exhibit D, SONAR [pp. 14, 23-24, 25-27]; SONAR Exhibit S-4 [p. 1]; EPA 2021	hearing transcript	M
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Clarifications and corrections to proposed rule language	There appears to be typographical errors in Subp. 3d and Subp. 4d, as the draft rule language in those subparts reference Class 2A instead of classes 2Bd and 2B, respectively.	Hearing Exhibit I-2; Attachment 2, Section H.2	Hearing Exhibit C	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0470	Request for additional information	Please confirm the water body identification code (WID) for West Crab Lake and Crab Lake. The proposed “Use Designation Tables for Lakes” (Exhibit S10 to the Statement of Need and Reasonableness (SONAR)) lists the WID for West Crab Lake as 69-0297-00 and the WID for Crab Lake as 69-0220-00. However, the existing rule language lists two different WIDs for West Crab Lake. Minn. R. 7050.0470, Subp. 2(B)(29) lists the WID for Crab Lake as 69-0220-00 and the WID for West Crab Lake as 69-0297-00, but Minn. R. 7050.0470, Subp. 2(B)(180) lists the WID for West Crab Lake as 69-0220-00.	Attachment 2, Sections G.3	SONAR Exhibit S-4 [pp. 90, 99, 114-117]; Hearing Exhibit D-1, SONAR Exhibit S-10 [pp. 2, 6]	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222; Minn. R. 7050.0150	Natural variability and Clarifications and corrections to proposed rule language	...it is unclear how MPCA or others implementing the criteria would determine which biological criterion applies to a specific lake. To provide clarity on how the biological criteria will apply, MPCA could either add definitions of the water body types to the proposed rules or more explicitly link the descriptions of the waterbody types in Minn. R. 7050.0222 to the groups in Bacigalupi et al. 2021.	Attachment 2, Sections D.3 and H.4	Schupp (1992); SONAR Exhibits S-5 [p. 3, 12-13, 27-50] and S-8 [p. 5]; Hearing Exhibit C	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Clarifications and corrections to proposed rule language	...Subp. 2 does not specify the averaging period or duration of the criterion. Not specifying the averaging period or duration will make the criteria difficult to interpret and implement. This can be avoided by providing additional details as to how the oxythermal habitat standard is to be implemented as a spatial and temporal average and how the averaging period or duration relate to protection of coldwater fish. For example, MPCA could provide additional information in the rule as to how many years of data should be included in the averaging period.	Attachment 2, Section H.3	Hearing Exhibit C	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Request for additional information	Additional explanation of MPCA’s decision-making would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2). ...MPCA determined site-specific criteria are appropriate because the low catch rate or population decline is due to factors other than elevated TDO3; however, the Coldwater TSD does not provide MPCA’s basis for this conclusion. Additional explanation of MPCA’s decision-making would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).	Attachment 2, Section G.5	SONAR Exhibit S-4	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Request for additional information	Data presented in Appendix C of the Coldwater TSD appear to show a declining trend in cisco populations and recreation suitability scores at Jessie Lake indicated non-attainment of recreation goals greater than 11% of the time. Because the available data suggest that the lake may not be supporting the coldwater aquatic life and recreation goals, MPCA set the proposed site-specific criteria for Jessie Lake “slightly below the current conditions.” Additional explanation of MPCA’s decision-making regarding the selection of the draft site-specific TDO3 criterion of 22.0°C and the site-specific total phosphorus criterion of 45 □g/L would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).	Attachment 2, Section G.5	SONAR Exhibit S-4	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Request for additional information	MPCA proposes site-specific TDO3, total phosphorus and chlorophyll-a criteria for Lake Itasca (WID 15-0016-00). Appendix C of the Coldwater TSD indicates that data for total phosphorus and chlorophyll-a are available from only two summer means, both of which appear to be from before 2010. Additional information about how MPCA evaluated the available data for this lake in developing the site-specific criteria would be helpful in demonstrating that requirements have been met under 40 CFR 131.5(a)(2).	Attachment 2, Section G.5	SONAR Exhibit S-4	post-hearing comment	N.1
David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0470	Request for additional information	Based on the descriptions in Appendix C, it appears that MNDNR’s designation decisions do not consider other coldwater fish, such as cisco or lake whitefish. The additional information listed below and identified for specific lakes in Table 1, would assist MPCA in documenting that it has met requirements under 40 CFR 131.5(a)(1). - For the 25 lakes proposed to be re-designated as Class 2B or Class 2Bd, additional information about whether these lakes support coldwater fish other than stream trout and are expected to be part of the subset that naturally support stream trout would help support the use change. For example, MPCA could provide additional information about whether any fisheries surveys conducted on these lakes documented the presence of coldwater fish species. - Information about the number of fisheries surveys conducted on each lake and why the available data are considered sufficient to conclude that coldwater fish are not present in the lake may be helpful in demonstrating that 40 CFR 131.5(a)(1) has been met.	Attachment 2, Section G.4	SONAR Exhibit S-4 [p. 53-58, Appendix C]	post-hearing comment	N.1

David Pfeifer, United States Environmental Protection Agency, Region 5	Minn. R. 7050.0222	Request for additional information	MPCA has proposed to revise the aquatic life use designation of Normanna Lake (WID 69-1383-00) from Class 2A to Class 2B because MNDNR intends to remove this lake from the trout water list. Because MNDNR's proposed removal of this lake from the trout water list is not final, it is possible that data will be presented to MNDNR that would lead to MNDNR maintaining the trout lake designation for Normanna Lake. The EPA encourages MPCA to verify that it has reviewed all available data before finalizing the proposed use designation for this lake.	Attachment 2, Section G.6	SONAR Exhibit S-4 [p. 85]	post-hearing comment	N.1

State of Minnesota
Minnesota Pollution Control Agency
Attachment 2 to MPCA Post-Hearing Response to Public Comments
MPCA Detailed Responses to Public Comments
November 23, 2026

This document supplements information in the Statement of Need and Reasonableness (SONAR; Hearing Exhibit D) in the matter of proposed amendments to Minnesota Rules, chapter 7050, relating to Water Quality Standards for Lake Aquatic Life and Recreation.

This document contains the Minnesota Pollution Control Agency's (MPCA or Agency) detailed responses to public comments on the proposed amendments submitted during the pre-hearing comment period (August 24–October 8, 2026) and at the public hearing held on November 2, 2026, as well as all post-hearing comments posted to the rulemaking's eComments page as of 12:00 pm on November 23, 2026 (post-hearing comments will be submitted into the rulemaking record as Exhibit N-1). The Agency thoroughly reviewed public comments, participated in the hearing, and reviewed the transcript of the hearing. This review resulted in the compilation of comments on multiple topics, which are addressed in detail in this document. All comments received during the pre-hearing comment period and the public hearing transcript are posted in their entirety on the MPCA webpage for this rulemaking at https://www.pca.state.mn.us/get-engaged/lake-aquatic-life-and-recreation.

The comment topics specifically addressed are:

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C. Comments recommending the implementation of additional protections for lakes 4
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C.2 Adding protections or scoring incentives to lakes with intact native plant shorelines 4
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C.4 Ensure TALU does not unintentionally reduce protection for modified or degraded lakes 6
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K. Comments related to 7050.0470 use classification tables 25

Summary of comments received in the matter of proposed amendments to Minnesota Rules, chapter 7050, relating to water quality standards for lake aquatic life and recreation.

The MPCA received comments during the pre-hearing comment period (August 24 - October 8, 2026), during the November 2, 2026, hearing on the proposed amendments to Minn. R. ch. 7050, and during the post comment hearing period (November 3-23, 2026). Comments were submitted which supported improved protections for coldwater fish habitats, refinements to eutrophication standards for lakes in the North region, and the adoption of a tiered aquatic life uses (TALU) framework for lakes. Several commenters sought additional information or asked the MPCA to clarify elements of the proposed amendments. Some commenters asked the MPCA to increase protection of Minnesota lakes through the implementation or enhancement of water quality management programs. One commenter was concerned that the proposed standards for coldwater lakes were not sufficiently protective. Other commenters requested that the MPCA address natural variability through use designations and standards and that the MPCA should involve local stakeholders in these decisions. The MPCA's responses to each stakeholder comment are provided below. The comments are grouped by topic, summarized, and the MPCA's response to these comments follows each summarized comment. A spreadsheet of these comments is also provided in Attachment 1. The MPCA also responded to a subset of the comments submitted in the prehearing comment period (see Hearing Exhibit I-2: Response to Pre-Hearing Comments). The MPCA appreciates the comments provided by stakeholders and the opportunity to provide additional information and to clarify aspects of the proposed rule amendments.

A. Comments in support of the proposed rule amendments

Relates to:
Minn. R. 7050.0150 (DETERMINING WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS);
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION);
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:
Summary of Proposed Amendments and Statement of General Need [pp. 13-16];
General reasonableness [pp. 32-40].

Summary of comments:
Multiple commenters expressed general support for the adoption of the proposed amendments and the goal of refining and strengthening protections for lakes. These comments were supportive of all three major elements in the proposed rule including revisions to coldwater lake standards, revisions to northern lake eutrophication standards, and the adoption of a TALU framework. Commenters expressing general support for the rule included: Geldner (Hearing Exhibit I-1.1), DonCarlos (Hearing Exhibit I-1.2), and Jefferis (Hearing Exhibit I-1.5).

MPCA response:
The MPCA appreciates the statements of support for the primary goals of this rulemaking which are to protect and restore water quality and to maintain aquatic life and recreation benefical uses (i.e., Class 2) in Minnesota lakes (Hearing Exhibit D, SONAR [pp. 13-16, 32-40]). This goal is consistent with the Clean Water Act's (CWA) objective to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. § 1251 (a)). Amending water quality standards (WQS) and use designations as needed to assign the correct goals to lakes will lead to better outcomes in the protection and restoration of these habitats.

B. Comments requesting the removal of the Class 7 designation

Relates to:
Minn. R. 7050.0140 (USE CLASSIFICATIONS FOR WATERS OF THE STATE);
Minn. R. 7050.0227 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 7 WATERS OF THE STATE; LIMITED RESOURCE VALUE WATERS).

Hearing Exhibit D (SONAR) discussion at:
Specific reasonableness [pp. 40-43].

Summary of comments:
The MPCA received a comment that the MPCA should remove the Class 7 use designation and eliminate this use designation from the list of use designations for the state. [Geldner (Hearing Exhibit I-1.1)].

MPCA response:
Modifications to use designations or the use classification framework other than those within Class 2 are outside of the scope for this rule. The SONAR details the scope of this rule which does not include revisions to Class 7 (Hearing Exhibit D, SONAR [pp. 40-43]). However, the MPCA will consider this comment beyond the current rulemaking because an objective of the MPCA is to continuously review WQS and make revisions when needed.

C. Comments recommending the implementation of additional protections for lakes

Relates to:
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION)

Hearing Exhibit D (SONAR) discussion at:
Specific reasonableness [pp. 40-43]
Coldwater lakes [pp. 34]

Other relevant documents:
Hearing Exhibit D-1, SONAR Exhibits S-5: MNDNR (2026) Development of a tiered aquatic life use framework for Minnesota lakes
Perleberg, D., P. Radomski, S. Simon, K. Carlson, C. Schirmers, J. Knopik, and B. Holbrook (2025) Minnesota Lake Plant Survey Manual, version 4. Minnesota Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN

C.1 Implementation of macroinvertebrate monitoring and assessments for lakes

Summary of comments:
The MPCA received a comment [Geldner (Hearing Exhibit I-1.1)] that the MPCA should Incorporate macroinvertebrate monitoring into lake assessments to improve biological condition assessments because these organisms are indicators of eutrophication, sediment oxygen depletion, and chemical disturbance.

MPCA response:
The MPCA agrees that the addition of additional biological monitoring tools such as macroinvertebrate assessments would improve the ability to determine the biological condition of lakes and to identify stressors. However, the development and implementation of such tools require significant resources which are currently not available. Although the development of macroinvertebrate or other biological tools are not within the scope of this rule (Hearing Exhibit D, SONAR [pp. 40-43]), the MPCA and Minnesota Department of Natural Resources (MNDNR) will continue to consider such improvements to lake management tools.

C.2 Adding protections or scoring incentives to lakes with intact native plant shorelines

Summary of comments:
The MPCA received a comment [Geldner (Hearing Exhibit I-1.1)] that the MPCA should protect natural shorelines because native littoral vegetation supports fish spawning, amphibians,

macroinvertebrates, and water quality and that TALU tiers should recognize and reward lakes with high-quality shoreline habitat.

MPCA response:
Although the specific request by the commenter is not within the scope of this rule (Hearing Exhibit D, SONAR [pp. 40-43]), the MPCA agrees that protections are needed for natural lake shorelines and native aquatic plants. There are existing programs which support such goals and the TALU framework is expected to enhance these programs. For example, the MNDNR performs Score the Shore surveys (Perleberg et al. 2025 [pp. 18-32]) as part of most fisheries surveys with priority given to completing surveys on lakes proposed as Exceptional Use. Lakes with intact shorelines are more likely to meet Exceptional Use goals and this information is used as part of the use designation review process (Hearing Exhibit D-1, SONAR Exhibit S-5 [Appendix A]). The linkage between high-quality fish communities and natural lake shorelines demonstrates the need to maintain these habitats to protect Exceptional Use lakes. The MNDNR encourages protection of high-quality shorelines through several programs. Lakes with Fish Index of Biotic Integrity (FIBI) scores above the Exceptional Use threshold are placed on a Lakes of Biological Significance (LOBS) list which includes lakes with high-quality fish, plant, bird, and amphibian communities. The LOBS list is used internally by the MNDNR as a criterion for acquisition prioritization and externally by non-governmental organizations (NGO) to prioritize shoreline conservation easements and acquisitions. The LOBS list may also be used by local governmental units (LGU) to inform their shoreline zoning regulations. The MNDNR also encourages natural shorelines by providing tools and resources online about how to complete a natural shoreline restoration project and coordinating with The Lake Steward Program, a statewide initiative in Minnesota run by Minnesota Lakes & Rivers Advocates in partnership with local lake associations and the MNDNR. The Program recognizes property owners who protect water quality and wildlife habitat by maintaining natural shorelines. The maintence of high-quality lakes through the protection of native shorelines will also be part of Watershed Restoration and Protection Strategies (WRAPS) studies. To summarize, Minnesota currently encourages protection and restoration of shorelines, and the adoption of the TALU framework will support these efforts by identifying lakes in need of protection and prioritizing management work.

C.3 Require tracking and additional oversight of herbicide use in lakes
Summary of comments:
The MPCA received a comment [Geldner (Hearing Exhibit I-1.1)] that the Agency should monitor lakes receiving herbicide treatments because these applications can affect dissolved oxygen, sediment chemistry, macroinvertebrates, and amphibians. Furthermore, Minnesota should require post-treatment biological monitoring to align lake management with aquatic life protection goals. This same commenter also recommended additional oversight and public tracking of herbicide treatments in lakes. Because a single lake can receive multiple herbicide permits from individuals, associations, and contractors, the MPCA should track cumulative chemical load to ensure aquatic life standards are not unintentionally compromised. A centralized database would allow citizens, researchers, and local governments to understand how much chemical treatment is occurring and where.

MPCA response:
Modification to the tracking and oversight of aquatic herbicide treatments are not within the scope of this rule (Hearing Exhibit D, SONAR [pp. 40-43]), but these treatments can be relevant to the

management of lake water quality. The permitting of herbicide applications is managed by the MNDNR through the Aquatic Plant Management and Invasive Aquatic Plant Management programs which follow the National Pollutant Discharge and Elimination System (NPDES)/State Disposal System (SDS) Vegetative Pests and Algae Control Pesticide General Permit. The MPCA does not directly manage permits for herbicide applications to lakes and these rule amendments do not directly affect herbicide permitting.

C.4 Ensure TALU does not unintentionally reduce protection for modified or degraded lakes

Summary of comments:

The MPCA received a comment [Geldner (Hearing Exhibit I-1.1)] that the MPCA should continue to encourage restoration and improvement of lakes. The commenter stated that lakes with intact native plant shorelines should receive higher protection and lakes with degraded littoral zones should not be permanently assigned lower expectations.

MPCA response:

The MPCA agrees that protection and restoration efforts are needed to manage lakes in Minnesota. The TALU framework and WQS do not allow the loss or removal of beneficial uses without a Use Attainability Analysis (UAA) as described in 40 CFR § 131.10(j)(2).[1] The proposed rule amendments do not affect these provisions in WQS and do not create a subclass to assign lower goals for Minnesota lakes (Hearing Exhibit D, SONAR [pp. 40-43]; also see Section I in this document).

C.5 Proposed coldwater lake standards are only minimally protective

Summary of comments:

The MPCA received a comment [Jefferis (Hearing Exhibit I-1.5)] that the MPCA should adopt coldwater standards that reflect the optimal conditions for the growth of non-human being populations.

MPCA response:

The MPCA does not disagree that protections for coldwater fishes and other aquatic organisms require a protection framework that maintains optimal conditions for these organisms when appropriate. However, this objective is accomplished by more than water quality standards which is the focus of these rule amendments. Water quality standards in most cases establish reasonable standards which at a minimum protect beneficial uses that are consistent with state and federal rules. However, these standards do not necessarily represent management targets for these lakes. For example, lakes which have better water quality than the standards are not managed such that the objective is to only meet the minimum goal required to maintain beneficial uses. Within water

[1] "(j) A State must conduct a use attainability analysis as described in § 131.3(g), and paragraph (g) of this section, whenever:

(1) The State designates for the first time, or has previously designated for a water body, uses that do not include the uses specified in section 101(a)(2) of the Act; or

(2) The State wishes to remove a designated use that is specified in section 101(a)(2) of the Act, to remove a sub-category of such a use, or to designate a sub-category of such a use that requires criteria less stringent than previously applicable." 40 CFR § 131.10(j)

quality standards there is a provision called "antidegradation"[2] which protects existing uses[3] and waters with water quality better than standards. The adoption of Exceptional Uses for some coldwater lakes and the work through WRAPS will also promote protection of these sensitive and important habitats. In addition, there are programs including the MNDNR's Cisco Refuge Lakes, Lakes of Biological Significance, and Lakes of Phosphorus Sensitivity which protect high-quality lakes. Together these proposed amendments to WQS will enhance existing programs which benefit coldwater habitats and organisms dependent on these habitats (Hearing Exhibit D, SONAR [pp. 34]).

D. Comments related to addressing natural variability through use designations and standards

Relates to:

Minn. R. 7050.0150 (DETERMINING WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS);
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION);
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:

General reasonableness [pp. 34, 52]
Statement of General Need, Northern Lakes [p. 14]
Background on Lakes WQS Rule, Revisions to Eutrophication Standards for Northern Lakes [pp. 23-24]
Background on Lakes WQS Rule, Adoption of a TALU Framework for Lakes [pp. 25-27]

Other relevant documents:

Schupp, D.H. (1992) An ecological classification of Minnesota lakes with associated fish communities. St. Paul: Minnesota Department of Natural Resources, Section of Fisheries.
EPA (2021) Ambient water quality criteria to address nutrient pollution in lakes and reservoirs. United States Environmental Protection Agency, Washington, D.C.
Hearing Exhibit D-1, SONAR Exhibit S-4: MPCA (2026) Development of water quality standards to protect coldwater lake habitats in Minnesota. Minnesota Pollution Control Agency: St. Paul, MN.
Hearing Exhibit D-1, SONAR Exhibit S-5: MNDNR (2026) Development of a tiered aquatic life use framework for Minnesota lakes
Hearing Exhibit D-1, SONAR Exhibit S-8: MNDNR (2026) Lake Index of Biological Integrity (IBI) Nearshore Sampling Manual. Minnesota Department of Natural Resources: Brainerd, MN.

D.1: Natural variability

Summary of comments: One commenter [Sip & Finney (I-1.3)] stated that the MPCA needs to consider natural variability, site-specific conditions, and climatic variability in lakes when developing standards and adopting beneficial uses. Another commenter [Silburn (Hearing Transcript)] asked the MPCA to clarify how it intends to facilitate the development of site-specific standards (SSS).

[2] Minn. R. 7050.0265 and Minn. R. 7050.0270
[3] Those uses attained in the surface water on or after November 28, 1975. See definition in Minn. R. 7050.0255, subp. 15.

MPCA response:
The MPCA agrees that natural variability and site-specific conditions should be addressed as part of WQS, use designations, and assessments. In fact, this rulemaking addresses this variability in several respects. The adoption of lake eutrophication standards for polymictic lakes addresses natural differences between dimictic and polymictic lakes (Hearing Exhibit D, SONAR [pp. 14, 23-24]). The proposed coldwater standards address the habitat requirements for different coldwater fish species and assign separate standards to each of these species (Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 1]). Furthermore, the proposed TALU framework also provides different management options for lakes depending on biological performance (Hearing Exhibit D, SONAR [pp. 25-27]). The MPCA will continue to consider how water quality standards can be refined and improved such that appropriate goals are assigned and to ensure that management of these resources is likely to result in meaningful outcomes for the protection and restoration of these waters.

The MPCA recognizes that in some cases SSS are required to manage unique lakes in Minnesota. The process of adopting SSS can often be cumbersome due to the need to collect large amounts of data to develop a standard which will protect benefical uses and to move these revisions through rulemaking. The MPCA understands that with the lake eutrophication standards and coldwater standards, unique attributes in Minnesota lakes may be relatively common due to the large number of lakes in the state. This requires a framework to develop and adopt SSS in a reasonable manner to assign appropriate goals to these waters. As a result, the MPCA intends to consider these needs more comprehensively by developing tools and adopting needed SSS for lake eutrophication in batches. For example, tools such as the United States Environmental Protection Agency's (EPA) lake eutrophication models (EPA 2021) may be used to develop eutrophication SSS.

D.2: Local stakeholder involvement
Summary of comments:
One commenter [Sip & Finney (I-1.3)] stated that the MPCA needs to involve local stakeholders early and throughout the process of implementing water quality standards including use designation determinations.

MPCA response:
The MPCA agrees and seeks local stakeholder involvement with implementation of WQS. Local stakeholders can have extensive knowledge of their local resources and can help with directing monitoring and water quality management activities. As part of the current Intensive Watershed Monitoring (IWM) framework, the first step involves engagement with local partners in IWM planning meetings to determine the sampling framework (i.e., where will sampling station be located and what parameters will be sampled). Local partners are also involved in the use designation and assessment of waters (e.g., Professional Judgement Group (PJG) meetings, impaired waters list comment period). The Agency is also interested in receiving feedback from stakeholders on rulemakings, including use designation rulemakings, and reasonably involves public stakeholders in these efforts. Even prior to individual rulemakings, stakeholders have the opportunity to comment on future water quality standards through the triennial standards review. We appreciate

this feedback, including hearing from local stakeholders as part of rulemakings. The MPCA will work to implement feedback suggestions when supported by evidence and consistent with state and federal rules.

D.3: Lake classification

Summary of comments:

Two commenters [Sip & Finney (I-1.3); Pfeifer (Exhibit N.1)] indicated that the terminology used for assignment of FIBI models was confusing because the term "shallow lake" is used. One commenter [Sip & Finney (I-1.3)] suggested that since the MPCA is replacing the term "shallow lake" with "polymictic lake," the MPCA could also change this terminology for the fish biocriteria framework to be consistent. Both commenters asked how lake type is determined for assignment of FIBI models to specific lakes. Specifically, Sip & Finney (I-1.3) asked how lake complexity is determined in this lake typology. This commenter also expressed that determination of Exceptional Uses designations should be based on clear and reproducible criteria.

MPCA response:

Regarding the use of the term "shallow lake" for the FIBI models, this framework is separate from that of the lake eutrophication standards framework. The lake eutrophication standards distinguish lake type based on stratification (i.e., polymictic versus dimitic) and although most shallow lakes are also polymictic lakes, the term polymictic lake[4] is preferable because it better delineates natural variation in trophic status. In contrast, the term "shallow lake" used as part of the FIBI model framework is based on a different lake typology and follows existing terminology defined by Schupp (1992). This classification creates groups of naturally similar lakes in Minnesota based on lake size, lake depth variables, lake fertility, and growing season length. To account for natural variability in fish communities, the MNDNR developed FIBIs using the Schupp lake classes. The MPCA agrees that additional information can be provided to clarify the distinction between these typologies. The MPCA and MNDNR will revise the technical support document for Tiered Aquatic Life Uses in Lakes (Hearing Exhibit D-1, SONAR Exhibit S-5 [p. 3]) to reference the Schupp class framework. In addition, the MPCA and MNDNR will add details to the Lake Index of Biological Integrity (IBI) Nearshore Sampling Manual (Hearing Exhibit D-1, SONAR Exhibit S-8 [p. 5]) to clarify how lake class is determined for specific lakes. The later document (Hearing Exhibit D-1, SONAR Exhibit S-8) is proposed to be incorporated by reference which codifies the methods for determining lake class into rule. Finally, the MPCA will update the lake class names in Minn. R. 7050.0222 subps. 2d, 3d, and 4d to reduce confusion with the term "shallow lake" (see section H.4 of this document). These revisions will also address a second point by the commenter and clarify how lake complexity is determined as well as how lake typology determinations are made in general.

Regarding the review and designation of Exceptional Uses the process for determining this use is provided in Hearing Exhibit D-1 (SONAR Exhibit S-5 [pp. 12-13]). In addition, examples of the data requirements and review process are provided in Hearing Exhibit D-1 (SONAR Exhibit S-5 [Appendix

[4] Polymictic lakes are lakes with frequent mixing of the water column during the ice-free period (see Hearing Exhibit D, p. 10).

A, pp. 27-50]). These determinations will be part of monitoring and assessment efforts with local partners and subject to public participation as required through rulemaking.

D.4: Designation of Cisco lakes

Summary of comments: One commenter [Silburn (Hearing Transcript)] asked for additional details regarding how the MPCA and MNDNR determined which lakes should be designated for the protection of Cisco.

MPCA response:

The MNDNR and MPCA reviewed fisheries survey (i.e., catch) data to determine which lakes support or supported populations of Cisco (i.e., confirmed presence) on or after the existing use date (November 28, 1975). This process is described in detail in the technical support document for the proposed coldwater standards revisions[5]. In this document, we refer to lakes with suitable habitat as those with oxythermal conditions that could support Cisco. However, this analysis did not necessarily consider other Cisco requirements such as spawning substrates and biogeography which may account for the absence of this species from lakes with suitable oxythermal habitat, and which were not included as lakes to be designated for the protection of Cisco. The focus of the use designation reviews was a demonstration that a population of this species was established in each lake on or after the existing use date and not a prediction of their occurrence based on abiotic factors. We should note that these reviews are based on available evidence and if future evidence demonstrates the presence of a Cisco population in a dimictic lake that is currently not included in the rule, it could be considered for designation in a future rule. For example, some of the lakes listed in Hearing Exhibit D-1 (SONAR Exhibit S-4 [Appendix E]) may be candidates for coldwater designation when additional data are collected.

[5] Hearing Exhibit D-1, SONAR Exhibit S-4 (MPCA (2026) Development of water quality standards to protect coldwater lake habitats in Minnesota) [pp. 50-56]

E. Comments related to the economic analysis

Relates to:
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION);
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:
Consideration of economic factors [pp. 49-61]

Other relevant documents:
Hearing Exhibit I-2: Response to Pre-Hearing Comments
Minn. Stat. § 116.07, subd. 6
Minn. Stat. § 115.43, subd. 1

E.1: Evaluation of the impacts to total maximum daily load (TMDL) and WRAPS studies

Summary of comments:
One commenter [Sip (Hearing Exhibit I-1.3)] requested that the MPCA provide additional information on counts of waterbodies in the Red River Basin affected by these standards and provide additional details regarding the effects and costs of implementing these revisions.

MPCA response:
The MPCA's response to this comment is provided in Hearing Exhibit I-2 [pp. 4-6] and the economic review is described in Hearing Exhibit D, SONAR [pp. 49-61]. Additional relevant responses to this comment are below in Section E.3 including how the MPCA considered the costs of implementing TMDLs, WRAPS, and other water quality management tools.

E.2: Evaluation of all more stringent and new parameters

Summary of comments:
Silburn (Hearing Exhibit I-1.4) requested that the MPCA clarify if the economic analysis included review of all parameters that would become more stringent as a result of the rule revision – including lakes with new Class 1B designations.

MPCA response:
As discussed in Hearing Exhibit I-2 [p. 3] and Hearing Exhibit D (SONAR [p. 57]), the MPCA reviewed all parameters that would be new or more stringent when Classes 1B and 2A are assigned to waters currently classified as Class 2B or Class 2Bd.

E.3: Estimating specific costs to permitted facilities

Summary of comments:
Silburn (Hearing Transcript) requested that the MPCA provide additional details regarding how the MPCA determined in the Economic Analysis that impacts will not be widespread since specific costs could not be determined.

MPCA response:

The MPCA understands that it is important to be transparent and to provide regulated parties with certainty when possible. However, reasonable and appropriate implementation of eutrophication and biological standards creates some uncertainties because of the need to address natural differences between habitat types and site-specific conditions. The objective of addressing natural variability through the adoption and implementation of WQS has been expressed as a requirement by stakeholders involved with the implementation of WQS, including in comments on these rule amendments (see Section D.1: Natural variability). To implement permits and other water quality management activities in a reasonable manner that supports the protection or restoration of beneficial uses, it is necessary to carefully review beneficial uses assigned to waters, review applicable standards, review the potential need for SSS, assess WQS, develop TMDLs, develop WRAPS, and write permits. The reasonable implementation of WQS can be complex due to the need for additional data, the connectedness of multiple waterbodies, and the presence of multiple permitted facilities adjacent to or upstream of a water of interest. The MPCA seeks to implement WQS with the collaboration of local organizations, Minnesota residents, and permittees to ensure that resources are used efficiently and that these efforts result in the protection or restoration of waters. As a result of following state and federal rules and the science when managing these waters as well as collaborating with stakeholders, the process of implementing aquatic life and recreation WQS can be complex and difficult to identify specific costs as part of a SONAR analysis.

Considering the detailed framework developed in Minnesota to reasonably implement WQS as summarized above, the MPCA reviewed all available data from lakes adjacent to or downstream of existing permitted facilities. The overall conclusion of this review is that the scope of impact to permitted facilities is small, but it is possible that a small number may need more restrictive permits to protect beneficial uses. The conclusion that costs to permitted facilities will not be large or widespread is based on several facts which were determined as part of an economic analysis and are delineated in Hearing Exhibit D, SONAR [pp. 49-61]. To summarize:

1) Most lakes that will receive more stringent standards under the proposed revisions (coldwater lakes and dimictic northern lakes) are concentrated in northern Minnesota where there are fewer permitted facilities;
2) The proposed amendments are largely revisions to existing standards which means only a subset of lakes will have more stringent standards and of those, standards for most parameters already apply; and
3) The determination of impairments, possible pollutant loading reductions, and the partition of any necessary load reductions is complex and requires detailed watershed-level analyses and modelling which may include multiple permits and waterbodies to ensure appropriate outcomes.

Considering these factors, the MPCA did an analysis to identify all permits upstream or adjacent to lakes that **could** become impaired as a result of the proposed revisions and only 15 facilities were identified. A detailed review of these lakes and permits within their lakesheds found that only 4 of these permits are likely to need reductions in total phosphorus loading (Hearing Exhibit D, SONAR [p. 58]). As discussed in Hearing Exhibit D, SONAR [pp. 58-59], specific costs or even if additional treatment is actually needed would be speculative and not relevant to whether these revisions to

WQS are needed to protect sensitive beneficial uses. If through the process of implementing WQS it is determined that additional treatment is required to protect or restore beneficial uses, the MPCA will engage early with regulated partners throughout this process. Any impacts to permittees will not occur within the next year as a result of the time required to assess standards and implement water quality management actions within watersheds which provide time for engagement with regulated partners. Importantly, the MPCA has notified permittees discharging to lakesheds with lakes that will receive more stringent standards as a result of these amendments (Hearing Exhibit D, SONAR [p. 66]) and provided additional details of potentially affected permittees in Hearing Exhibit I-2. These steps will allow the small number of permittees that may be affected by these amendments to be involved early in the process of implementing protections for these sensitive and important lakes.

F. Comments related to maintence of multiple benefits

Relates to:
Minn. R. 7050.0150 (DETERMINING WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS);
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION);
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:
TALU framework for lakes [p. 38]

Summary of comments:
One commenter [Sip & Finney (I-1.3)] stated that projects involving flood impoundments, diversions, channel restoration, grade control structures, wetland restoration, floodwater storage, drainage improvements, and other hydrologic modifications should be evaluated according to their overall environmental and public benefits and that the MPCA should coordinate with watershed districts early in project development rather than allowing biological or water quality standards to become an obstacle late in permitting.

MPCA response:
The proposed rule amendments do not disallow local stakeholders from implementing multipurpose projects. Although local stakeholders may need to consider if implementation of hydrologic modifications will result in the loss of an existing use, the proposed amendments do not add this requirement. These amendments do assign some beneficial uses that carry with them more stringent standards, which could result in the need to determine if such projects could cause the loss of an existing use (Hearing Exhibit D, SONAR [p. 38]). In these situations, the objective would be to develop the project such that it supports multiple purposes including both the hydrologic and aquatic life and recreation benefits. Ultimately, the protection of these habitats will be more cost effective compared to trying to restore them, especially after costly infrastructure has been built. As part of implementing these standards, the MPCA will seek early coordination and input from local stakeholders as part of the implementation of WQS (see comments in section D.2 of this document).

G. Comments requesting additional information

Relates to:

Minn. R. 7050.0150 (DETERMINING WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS);
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION);
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:

Background on Lakes WQS Rule [p. 23 (footnote 13)]
Specific reasonableness [p. 41]

Other relevant documents:

SONAR Exhibits (Hearing Exhibit D-1): S-3 - MPCA (2025) Development of eutrophication standards for northern lakes in Minnesota. Minnesota Pollution Control Agency: St. Paul, MN.
Hearing Exhibit I-2: Response to Pre-Hearing Comments
SONAR Exhibits (Hearing Exhibit D-1): S-10 - Draft beneficial use tables for lakes
Hearing Exhibit D-1, SONAR Exhibit S-4 - MPCA (2026) Development of water quality standards to protect coldwater lake habitats in Minnesota. Minnesota Pollution Control Agency: St. Paul, MN.

G.1: Shallow lakes

Summary of comments: One commenter [Sip & Finney (I-1.3)] requested clarification regarding whether eutrophication standards still apply to shallow lakes and if further revisions to rule language are needed to clarify the application of eutrophication standards to shallow lakes.

MPCA response:

The MPCA does not intend to remove eutrophication standards to most shallow lakes as they are currently defined. The MPCA is proposing to replace the term “shallow lake” with “polymictic lake” to provide a more scientifically definable term for these lakes which is linked to nutrient processes that affect the standards needed to protect beneficial uses (Hearing Exhibit D, SONAR [pp. 23 (footnote 13), 41]; SONAR Exhibit S-3 (Hearing Exhibit D-1) [pp. 12-13]). Although shallow lakes (as currently defined in rule) and polymictic lakes (a defined in the proposed rule language) are not perfect analogs, there is a large degree of overlap in practice. As a result, the rule revisions to the terminology do not greatly impact the applicability of lake eutrophication standards. To provide additional clarity in rule, the MPCA is proposing additional revisions to rule language (see below in Section H.1).

G.2: Request for a list of specific permits and lakes used in the economic analysis

Summary of comments:

One commenter [Silburn (Hearing Exhibit I-1.4)] requested that the MPCA provide specific names for permits and lakes that were identified as part of the Economic Analysis in the SONAR.

MPCA response:
The requested lists are provided in Hearing Exhibit I-2 (pp. 1-3).

G.3: Confirmation of WID for West Crab Lake

Summary of comments:
One commenter [Pfeifer (Exhibit N.1)] requested that the MPCA confirm the waterbody identification (WID) codes for lakes listed as Crab Lake and West Crab Lake in the proposed amendments.

MPCA response:
The MPCA checked all references to lakes named Crab Lake and West Crab Lake in the proposed amendments and supporting documentation (Hearing Exhibit D-1, SONAR Exhibit S-4 [pp. 89, 99, 114, 116-117]; Hearing Exhibit D-1, SONAR Exhibit S-10 [pp. 2, 6]) and can confirm the WID codes are correct. Some of the confusion is that there are two Crab lakes included in this rule. Two of the lakes are located within the Boundary Waters Canoe Area Wilderness (BWCAW) in St. Louis County: Crab Lake (69-0220-00) and West Crab Lake (69-0297-00). Crab Lake (69-0220-00) is currently designated Class 2A to protect stream trout. This lake does not support a stream trout population but does have a Cisco population. Therefore, it is proposed to be designated Class 2A[TLC] to protect the Cisco population (Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 99]). West Crab Lake (69-0297-00) is connected to Crab Lake (69-0220-00) and was included in the Class 2A designation for stream trout, but it does not support stream trout, and it is too shallow to support Cisco during the summer. Therefore, it is proposed to be designated Class 2Bd to protect the warm water habitat (Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 117]). Crab Lake (16-0357-00) is located just outside the BWCAW in Cook County. Crab Lake (16-0357-00) was designated Class 2A to protect stream trout, but there is no evidence that a coldwater fishery was established, and the lake is very shallow (Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 116]). As a result, the MPCA is proposing to designate this lake Class 2Bd to protect the warm water habitat. The use designation proposals for these 3 lakes are accurately reflected in the draft use designation tables (Hearing Exhibit D-1, SONAR Exhibit S-10 [pp. 2, 6]).

G.4: Request for additional fishery survey information for coldwater lake reviews

Summary of comments:
One commenter [Pfeifer (Exhibit N.1)] requested that the MPCA provide additional fishery survey data to confirm that the proposed Class 2Bd designations are consistent with 40 CFR 131.5(a)(1). Specifically, the commenter requested that the MPCA provide information on the presence or absence of other coldwater fish species (e.g., Cisco and Lake Whitefish) and the numbers of fishery surveys in the Class 2Bd designation descriptions.

MPCA response:
The MPCA is providing additional fisheries information that confirms the lack of coldwater habitat on or after November 28, 1975, for the 25 lakes proposed to be designated Class 2Bd. These data are summarized in the table below. Full write ups are provided in Appendix C of SONAR Exhibit S-4 (Hearing Exhibit D-1). For some lakes, a single fishery survey or no fishery surveys were available. In these cases, additional information (e.g., oxythermal habitat, lake morphology) was used to

determine that the lake was unlikely to support a self-sustaining population of coldwater fish. These use designation reviews are consistent with the methods in SONAR Exhibit S-4 (Hearing Exhibit D-1 [p. 52-56]) which describes evidence besides fishery surveys that may be used to support use designations.

Lake Name	WID	Fisheries surveys reviewed	Species absent from surveys	Notes
Cone, Upper	16-0412-00	1981, 1984, 1987	LAT, LKW, TLC, SRT	No coldwater fish species sampled in 3 surveys
Devilfish	16-0029-00	1955, 1984, 1985, 1986, 1989, 1992, 1998, 2004, 2008, 2012, 2016, 2020	LKW, TLC	LAT sampled in 1955; BKT sampled in 1985 but transients from a connected managed SRT stream
Hungry Jack	16-0227-00	1980, 1982, 1984, 1986, 1988, 1989, 1991, 1994, 1997, 2001, 2004, 2008, 2012, 2016, 2020	LKW, TLC	LAT sampled in 1982, 1986, 2001, 2004, SRT sampled in 1984, RBT sampled in 1994 but a transient from a connected managed SRT lake
Lizz	16-0199-00	1984, 1994, 1998, 2002, 2013	LAT, LKW, TLC	BKT sampled in 1994, 1998, 2002, 2013 but of stocked origin and stocking discontinued due to northern pike predation
Mulligan	16-0389-00	1985, 1990, 1993, 1997, 2004	LAT, LKW, TLC	BKT sampled in 1985, 1990, 1993, 1997, 2004 but of stocked origin and stocking discontinued due to northern pike predation
Omega (Onega)	16-0353-00	1939	not applicable	1939 fisheries survey sampled only Northern Pike and recommended that fish should not be stocked until the Northern Pike population was reduced
Otto, South	16-0323-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a small (17 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Vista	16-0224-00	1985, 1993	LAT, LKW, TLC, SRT	No coldwater fish species sampled in 2 surveys
Wanihigan	16-0349-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a small (19 ha), relatively shallow (12 m) lake that is unlikely to support a self-sustaining population of coldwater fish
Normanna	69-1383-00	1977, 1980, 1991, 1996	LAT, LKW, TLC	BKT sampled in 1980, 1991, 1996 but of stocked origin and stocking discontinued (surveys recorded under incorrect lake (Unnamed Lake (69-0122-00)))

Lake Name	WID	Fisheries surveys reviewed	Species absent from surveys	Notes
Unnamed	69-0122-00	not applicable	not applicable	No survey records available to confirm coldwater species presence (Normanna (69-1383-00) survey records incorrectly entered in Unnamed Lake (69-0122-00) records); shallow (1.4 m) with a small surface area (0.9 ha) - not suitable for Lake Trout, Lake Whitefish, Cisco, or the management of a stream trout fishery
Mirror	69-0234-00	1990, 1992, 1994, 1996, 2001	LAT, LKW, TLC	BNT sampled in 1992, 1994, 1996, 2001 but of stocked origin and stocking discontinued due to competition with cool water species
Agamok	38-0011-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a shallow (9 m), relatively small (43 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Arkose	38-0382-00	1979	LAT, LKW, TLC, SRT	One survey indicates no coldwater fish species present; shallow (6 m), small (8 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Beartrack	69-0480-00	1965, 1966, 1967, 1974, 2000	LAT, LKW, TLC, SRT	5 fisheries surveys; no LAT or LKW sampled; 1 TLC sampled in 1966 but likely transient from connected lakes
Big Ruby	69-0333-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a relatively shallow (15 m) small (17 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Brandt	16-0600-00	1979	LAT, LKW, TLC, SRT	One survey indicates no coldwater fish species present; assessments of oxythermal habitat determined conditions were “marginal” or not suitable for trout
Crab	16-0357-00	1987, 1997, 2002, 2007, 2010, 2023	LAT, LKW, SRT	TLC sampled in 1987, 1997, 2023, but polymictic
Marble	38-0109-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a small (21 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Mora	16-0732-00	1987	LAT, LKW, TLC, SRT	One survey indicates no coldwater fish species present; assessments of oxythermal habitat determined conditions were “marginal” or not suitable for trout

Lake Name	WID	Fisheries surveys reviewed	Species absent from surveys	Notes
Tarry	16-0731-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a small (15 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Virgin	16-0719-00	1980	LAT, LKW, TLC, SRT	No survey records available to confirm coldwater species presence; however, this is a small (23 ha), relatively shallow (12 m) lake that is unlikely to support a self-sustaining population of coldwater fish
West Crab	69-0297-00	not applicable	not applicable	No survey records available to confirm coldwater species presence; however, this is a shallow (5 m), likely polymictic lake that is unlikely to support a self-sustaining population of coldwater fish
East Twin	03-0362-00	1966	LAT, LKW, TLC, SRT	One survey indicates no coldwater fish species present; this is also a small (5 ha) lake that is unlikely to support a self-sustaining population of coldwater fish
Kennedy	31-0137-00	1959, 1963, 1969, 1970, 1972, 1977, 1986, 2003	LAT, LKW, TLC, SRT	No coldwater fish species sampled in 8 surveys
Willard	11-0564-00	1989, 1994, 1995, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008	LAT, LKW, TLC	RBT sampled in 1989, 1994, 1995, 1998, 2000, 2002, 2003, 2006, 2007 but of stocked origin and stocking discontinued due to competition with warmwater species

G.5: Request for additional data to support proposed site-specific coldwater lake standards

Summary of comments:

One commenter [Pfeifer (Exhibit N.1)] requested that the MPCA provide additional information to justify some of the proposed SSS for coldwater lakes. The commenter noted that for some lakes with proposed SSS, the coldwater fish populations appear to be low or declining which may indicate the SSS is not sufficiently protective of the beneficial use as required by 40 CFR 131.5(a)(2). This commenter specifically asked for additional documentation of the technical basis for the proposed SSS for Jessie Lake (justify SSS more stringent than current conditions) and Lake Itasca (additional data).

MPCA response:

The MPCA prefers to provide a full justification as required by 40 CFR 131.5(a)(2) for these proposed SSS. The time constraints of the period for the response to comments does not allow the MPCA to provide this and as a result, the MPCA will remove all 11 SSS from the proposed rule as referenced in Hearing Exhibit D-1, SONAR Exhibit S-4. This does not affect any of the proposed rule language.

Many of these lakes and others will likely require SSS, but the MPCA will address these in detail in future rules.

G.6: Request for documentation of trout water status for Normanna Lake

Summary of comments:

One commenter [Pfeifer (Exhibit N.1)] requested that the MPCA provide additional information supporting the removal of the Class 2A designation from Normanna Lake (69-1383-00).

MPCA response:

The MPCA would like to clarify that these rule revisions do not propose the removal of the Class 2A designation for Normanna Lake (69-1383-00). This lake is currently designated Class 2B and therefore there is no proposed change to the use designations for this lake. The MPCA incorrectly designated an unnamed lake (69-0122-00) as a coldwater lake instead of designating Normanna Lake (69-1383-00). As a result, the lake the MNDNR was managing as a stream trout fishery (Normanna Lake (69-1383-00)) was never designated Class 2A. The MNDNR is in the process of removing the trout water designation (Minn. R. 6264.0050) from Normanna Lake (69-1383-00) and therefore the MPCA will not propose to change this lake from Class 2A to Class 2B. Regarding the change of the Class 2A designation to Class 2Bd for the unnamed lake (69-0122-00), this waterbody was not managed for stream trout and is shallow (1.4 m feet maximum) with a small surface area (0.9 ha). This waterbody is too small and shallow to support Lake Trout, Lake Whitefish, or Cisco and would not be suitable for the management of a stream trout fishery. As a result, it is reasonable to remove the Class 2A designation from this waterbody and replace it with Class 2Bd. This proposal is documented in Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 84-85].

H. Clarifications and corrections to proposed rule language

Relates to:
Minn. R. 7050.0150 (DETERMINING WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS);
Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION).

Hearing Exhibit D (SONAR) discussion at:
Specific reasonableness [pp. 41, 42]

Other relevant documents:
Hearing Exhibit C: Proposed rule, including Revisor's approval

H.1: Shallow lakes definition

Summary of comments:
One commenter [Sip & Finney (I-1.3)] asked if further revisions to rule language are needed to clarify the application of eutrophication standards to shallow lakes.

MPCA response:
The proposed rule language (Hearing Exhibit C) is being revised to be clearer and to follow better defined scientific terms. The term "polymictic lake" largely replaces "shallow lake." However, since the term "shallow lake" is no longer used in rule, it is reasonable to remove this definition. The Agency will propose to remove this definition from Minn. R. 7050.0150 for clarity.

Proposed modifications based on public comments:
Guide to tracking modifications to the proposed rule language as published in the State Register on August 24, 2026 (Hearing Exhibit C): The black text, including black underlines and black strikethrough font, shows the applicable rule provisions as published. Red underlined font shows new text the MPCA is proposing to adopt that was not in the rule amendments as published.

Minn. R. 7050.0150, Subp. 4.

…

~~MM. "Shallow lake" means an enclosed basin filled or partially filled with standing fresh water with a maximum depth of 15 feet or less or with 80 percent or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (the littoral zone). It is uncommon for shallow lakes to thermally stratify during the summer. The quality of shallow lakes will permit the propagation and maintenance of a healthy indigenous aquatic community and they will be suitable for boating and other forms of aquatic recreation for which they may be usable. Shallow lakes are differentiated from wetlands and lakes on a case-by-case basis. Wetlands are defined in part 7050.0186, subpart 1a.~~

…

H.2: Correction to proposed rule language in Minn. R. 7050.0222, subps 3d and 4d

Summary of comments:
Two commenters [Sip & Finney (I-1.3); Pfeifer (Exhibit N.1)] identified a drafting error in the proposed rule language for Minn. R. 7050.0222.

MPCA response:
The MPCA appreciates the commenters' identification of this error and will correct this error to the proposed rule language (Hearing Exhibit C). These additional revisions are documented below.

Proposed modifications based on public comments:
Guide to tracking modifications to the proposed rule language as published in the State Register on August 24, 2026 (Hearing Exhibit C): The black text, including black underlines and black strikethrough font, shows the applicable rule provisions as published. Red underlined font shows new text the MPCA is proposing to adopt that was not in the rule amendments as published. These modifications also show the revisions described in Section H.4 of this document.

Minn. R. 7050.0222, subp 3d

Subp. 3d. **Biological criteria for lotic warm or cool water aquatic life and habitats (class 2Bd).**

Water Body Type	Tier	Class	Assemblage	Biocriterion
… …	…	…	…	
Deep, complex lakes	Exceptional	2BdAe	Fish	64
	General	2BdAg	Fish	45
Deep, simplemoderately complex lakes	Exceptional	2BdAe	Fish	59
	General	2BdAg	Fish	38
Moderately shallow, vegetated deep lakes	General	2BdAg	Fish	24
Shallow, productive lakes	General	2BdAg	Fish	36

…

Minn. R. 7050.0222, subp 4d

Subp. 4d. **Biological criteria for lotic warm or cool water aquatic life and habitats (class 2B).**

Water Body Type	Tier	Class	Assemblage	Biocriterion
…				
Deep, complex lakes	Exceptional	2BAe	Fish	64
	General	2BAg	Fish	45
Deep, simplemoderately complex lakes	Exceptional	2BAe	Fish	59
	General	2BAg	Fish	38
Moderately shallow, vegetated deep lakes	General	2BAg	Fish	24
Shallow, productive lakes	General	2BAg	Fish	36

…

H.3: Averaging period for oxythermal habitat criteria

Summary of comments:
One commenter [Pfeifer (Exhibit N.1)] suggested that additional details regarding the assessment requirements for T_{DO3} would assist with implementation of the standard.

MPCA response:
The MPCA will propose to add additional implementation details to Minn. R. 7050.0222 subp. 2 (Hearing Exhibit C) to clarify assessment requirements for T_{DO3}. These additional revisions are documented below.

Proposed modifications based on public comments:
Guide to tracking modifications to the proposed rule language as published in the State Register on August 24, 2026 (Hearing Exhibit C): The black text, including black underlines and black strikethrough font, shows the applicable rule provisions as published. Red underlined font shows new text the MPCA is proposing to adopt that was not in the rule amendments as published.

…
An average of maximum T_{DO3} (temperature at 3 mg/L of dissolved oxygen) sufficient to support coldwater fish species must be maintained. For assessments, maximum T_{DO3} must be calculated as an average of a minimum of three years which were measured within the most recent 10 years at the time of assessment. The following are specific to lakes supporting different coldwater fish species:
…

H.4: Lake class names for fish biocriteria

Summary of comments:
Two commenters [Sip & Finney (I-1.3); Pfeifer (Exhibit N.1)] indicated that the terminology used for assignment of FIBI models was confusing because the term "shallow lake" is used.

MPCA response:
The MPCA will propose to modify the lake class terminology in the proposed rule language (Hearing Exhibit C) in Minn. R. 7050.0222 subps. 2d, 3d, and 4d to reduce confusion regarding the term "shallow lake" and to simply terminology (see Section D.3 of this document). These additional revisions are documented below.

Proposed modifications based on public comments:
Guide to tracking modifications to the proposed rule language as published in the State Register on August 24, 2026 (Hearing Exhibit C): The black text, including black underlines and black strikethrough font, shows the applicable rule provisions as published. Red underlined font shows new text the MPCA is proposing to adopt that was not in the rule amendments as published. These modifications also show the revisions described in Section H.2 of this document.

Minn. R. 7050.0222, subp 2d

Subp. 3d. **Biological criteria for lotic warm or cool water aquatic life and habitats (class 2Bd).**

…

Water Body Type	Tier	Class	Assemblage	Biocriterion
…				
Deep, complex lakes	Exceptional	2Ae	Fish	64
	General	2Ag	Fish	45
Deep, simple~~moderately complex~~ lakes	Exceptional	2Ae	Fish	59
	General	2Ag	Fish	38
Moderately shallow, vegetated ~~deep~~ lakes	General	2Ag	Fish	24
Shallow, productive lakes	General	2Ag	Fish	36

…

Minn. R. 7050.0222, subp 3d

Subp. 3d. **Biological criteria for lotic warm or cool water aquatic life and habitats (class 2Bd).**

…

Water Body Type	Tier	Class	Assemblage	Biocriterion
…				
Deep, complex lakes	Exceptional	2BdAe	Fish	64
	General	2BdAg	Fish	45
Deep, simple~~moderately complex~~ lakes	Exceptional	2BdAe	Fish	59
	General	2BdAg	Fish	38
Moderately shallow, vegetated ~~deep~~ lakes	General	2BdAg	Fish	24
Shallow, productive lakes	General	2BdAg	Fish	36

…

Minn. R. 7050.0222, subp 4d

Subp. 4d. **Biological criteria for lotic warm or cool water aquatic life and habitats (class 2B).**

…

Water Body Type	Tier	Class	Assemblage	Biocriterion
…				
Deep, complex lakes	Exceptional	2BAe	Fish	64
	General	2BAg	Fish	45
Deep, simple~~moderately complex~~ lakes	Exceptional	2BAe	Fish	59
	General	2BAg	Fish	38
Moderately shallow, vegetated ~~deep~~ lakes	General	2BAg	Fish	24
Shallow, productive lakes	General	2BAg	Fish	36

…

I. Comments related to the development of a Modified Use for lakes

Relates to:

Minn. R. 7050.0222 (SPECIFIC WATER QUALITY STANDARDS FOR CLASS 2 WATERS OF THE STATE; AQUATIC LIFE AND RECREATION).

Relevant documents:

SONAR Exhibit S-5 (Hearing Exhibit D-1): MNDNR (2026) Development of a tiered aquatic life use framework for Minnesota lakes

Hearing Exhibit I-2: Response to Pre-Hearing Comments

Summary of comments:

One commenter [Sip & Finney (I-1.3)] asked why the MPCA did not consider a Modified Use for lakes similar to the framework for streams.

MPCA response:
As discussed in Hearing Exhibit I-2 [p. 8] and Hearing Exhibit D-1 (SONAR Exhibit S-5 [p. 6]), a Modified Use tier for lakes was considered, but the MPCA and MNDNR determined that such a tier was not needed because few lakes would fit into this category as defined by the requirements of the Clean Water Act for the removal of a use (see 40 CFR 131.10(g)).

J. Comments related to the Class 1 designation

Relates to:
Minn. R. 7050.0420 (COLDWATER HABITAT WATERS)

Hearing Exhibit D (SONAR) discussion at:
Protection and Restoration of Aquatic Life Beneficial Uses [p. 22 (body text and footnote 10)]
Hearing Exhibit D, SONAR [pp. 27-28]

Relevant documents:
Hearing Exhibit I-2: Response to Pre-Hearing Comments
Hearing Exhibit D-1, SONAR Exhibit S-4 - MPCA (2026) Development of water quality standards to protect coldwater lake habitats in Minnesota. Minnesota Pollution Control Agency: St. Paul, MN.
State Register, 1 June 2020, Volume 44, Number 49 [p. 1416]
State Register, 26 June 2023, Volume 47, Number 52 [p. 1207]

Summary of comments:
One commenter [Silburn (Hearing Exhibit I-1.4; Hearing Transcript)] asked how many lakes proposed to be assigned Class 2A would also be designated Class 1B and if the MPCA specifically evaluated the Class 1B designation for these lakes.

MPCA response:
The MPCA is only proposing changes to Class 2 designations; however, the assignment of Class 2A automatically assigns the Class 1B designation (Minn. R. 7050.0420, Item D). In these rule amendments, there are 346 lakes which are proposed to go from Class 2B to Class 2A which carries with it the Class 1B designation (Hearing Exhibit D, SONAR [pp. 22 (body text and footnote 10); 27-28]; Hearing Exhibit D-1, SONAR Exhibit S-4 [p. 3]; Hearing Exhibit I-2 [pp. 3-4]). There are also 65 lakes which are currently designated Class 2Bd which are proposed to be designated Class 2A. These lakes are already designated Class 1B. Class 2A waters already assigned Class 1B, which are proposed to change to Class 2B will retain the Class 1B designation and be designated Class 2Bd.

The linkage between these use designations was established because there is often a connection between surface and ground water in coldwater surface water habitats. To protect ground water sources of drinking water (i.e., domestic consumption), the drinking water standards are applied to Class 2A lakes and streams. As discussed in Hearing Exhibit I-2 [pp. 3-4], The evaluation of domestic consumption uses (Class 1) was not within scope for this rule as only aquatic life uses (Class 2) were reviewed. The process of automatically assigning Class 1B to Class 2A waters, as required by Minn. R.

7050.0420, without specific evaluation of the Class 1B designation is consistent with past rule amendments (e.g., State Register, 1 June 2020, Volume 44, Number 49, [p. 1416]; State Register, 26 June 2023, Volume 47, Number 52 [p. 1207]).

K. Comments related to 7050.0470 use classification tables

Relates to:
Minn. R. 7050.0470 (CLASSIFICATIONS FOR SURFACE WATERS IN MAJOR DRAINAGE BASINS).

Hearing Exhibit D (SONAR) discussion at:
Listing use designations in Minn. R. 7050.0470 through incorporations by reference [p. 28-29].

Other relevant documents:
Hearing Exhibit I-2: Response to Pre-Hearing Comments
SONAR Exhibits (Hearing Exhibit D-1): S-10 - Draft beneficial use tables for lakes

Summary of comments:
A commenter [Silburn (Hearing Exhibit I-1.4)] requested that the MPCA confirm if rulemaking is required to change or add beneficial use designations to the lists incorporated by reference.

MPCA response:
The process for designating uses to waters will be unchanged by the proposed rule amendments and will require rulemaking to change designated beneficial uses. The use of documents incorporated by reference is currently the system used to document stream designations. As authorized by Minn. R. 7050.0470, the MPCA currently maintains tables of use classifications for stream reaches by water basin in Minnesota. These use designation tables are found at: https://www.pca.state.mn.us/get-engaged/incorporations-by-reference. The draft use designation tables for lakes are provided as a SONAR exhibit (Hearing Exhibit D-1, SONAR Exhibit S-10). The MPCA also responded to this comment in Hearing Exhibit I-2 [pp. 4].

Katie Izzo Attachment 2

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Minnesota Department of Natural Resources
Investigational Report 417, 1992

AN ECOLOGICAL CLASSIFICATION OF MINNESOTA LAKES WITH ASSOCIATED FISH COMMUNITIES[1]

Dennis H. Schupp

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Abstract--Limnological variables from 3,029 Minnesota lakes were used to ecologically classify the lakes into 44 types. Principal components analysis classified the variables into three types: variables associated with lake size; variables associated with lake depth; and variables associated with the chemical fertility of the lakes, and length of the growing season. Reductions in sums of squares due to classification ranged from 56 to 89% for six physical and chemical variables. Gill and trap net catch indices within lake classes were used to characterize fish communities for each lake class. Intra-class variation of gill and trap net CPUE and mean weights of 23 species of fish were also reduced. Variation in these measures, however, remains high. Examples of the use of inter-quartile ranges of CPUE and average size for rapid assessment of lake survey results are presented. The classification and recommended evaluation of netting surveys is intended to stimulate analysis of surveys from an aquatic community viewpoint. This approach can aid fishery managers to quickly separate likely problems from natural biological variation. Their time and resources should thus be used more effectively.

Introduction

Nearly all lakes in Minnesota were formed by glacial action (Schwartz and Thiel 1954), but they vary widely in limnological characteristics. The species and community assemblages of fish are usually those best adapted to the unique conditions in a lake. Rational management of the lakes for fish production should consider the community structure best suited for a lake.

Moyle (1946) found that the chemical parameters, total alkalinity and total phos phorous, were useful predictors of pond productivity and were related to total fish caught in lake survey gill nets. Moyle concluded that lake productivity must be evaluated in the light of water quality and lake basin form. He also cited Thompson (1941) that length of the growing season and water temperature are also important when lakes in different latitudes and altitudes are compared. Minnesota covers a range of 5° 30' latitude.

Rounsefell (1946) concluded that fish production was related to the size of the water body, and that the smaller the lake the greater was the production of fish per unit

[1] This project was funded in part by the Federal Aid in Sport Fish Restoration (Dingell-Johnson) Program. Completion Report, Study 666 (312), D-J Project F-26-R Minnesota.

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area. Rawson (1952) showed that mean depth was related to fish production. Ryder (1965) combined chemical and physical factors (TDS and mean depth) to develop the widely used Morphoedaphic Index (MEI).

More recently, multivariate analysis techniques have been used to classify lakes and community types. Johnson et al. (1977) used principal component and discriminant analysis to classify 2,496 Ontario lakes that sorted into 15 groups based on the presence or absence of four game fish species: walleye *Stizostedion vitreum*, northern pike *Esox lucius*, lake trout *Salvelinus namaycush*, and smallmouth bass *Micropterus dolomieu*. Canonical discriminant analysis was used to assess the degree to which the species associations could be identified using limnological variables. This work has been extended, adding brook trout *Salvelinus fontinalis* and lake whitefish *Coregonus clupeaformis*. Ontario has classified all inventoried lakes into one of 63 community assemblage types (Ontario Ministry of Natural Resources 1978). Tonn et al. (1983) used ordination, classification, and discriminant analysis to study the fish assemblages in 18 small Wisconsin lakes. They used the results of the discriminant analysis to successfully predict the fish assemblage in 11 additional lakes using five variables: area, maximum depth, pH, watershed size, and conductivity. Dolman (1990) used cluster analysis to classify 132 Texas reservoirs into five groups based on species associations. Canonical correlation was used to analyze relations between the species associations and environmental variables.

Lake surveys in Minnesota began in 1935 (Moyle 1946). Early surveys included contour maps that showed the extent and nature of aquatic vegetation and bottom-soil types, and measurements of water temperatures, DO, pH, total alkalinity, and TDS. Fish were sampled by gill nets and seines. Trap nets were added as a fish sampling gear in 1951, and since then survey methods have been standard. Most surveys are of short duration lasting one week or less.

Though the earliest effort at classification of Minnesota fish lakes was made by Eddy (1938), it was the work of Moyle (1946; 1950) that led to the development of a classification system for Minnesota lakes that has been used for more than 30 years. The principal parameters used in the classification were the size and depth of the lake, and total alkalinity. Scidmore (1970) listed seven ecological lake types. While the system has been useful, it has also been misused. Fishery managers frequently assigned an ecological classification to a lake based on the species for which they were managing. This often depended on the fish that were being stocked, and sometimes resulted in the lake being reclassified with each change of management objectives.

Abundances of fish were judged by comparing lake survey net catches to statewide median net catches without reference to the lake type (Moyle 1950; Moyle and Lound 1960; Scidmore 1970). The number and sizes of fish caught in survey nets are usually interpreted only as measures of abundance, but net catches also reflect the response of fish to their particular environment.

The purpose of this study was: (1) to develop a refined ecological classification of Minnesota's fish lakes using limnological variables measured during lake surveys; (2) to evaluate factors that influence lake survey net catches of fish; and (3) to establish benchmarks other than statewide medians for evaluating lake survey net catches of fish. The results of this analysis should allow fishery managers to make more realistic judgments of the status of fish communities from lake surveys by considering conditions in the particular lake at the time of the survey.

Materials and Methods

Data used for this study were from 5,625 lake surveys. Most of the surveys were done from 1974 through 1986 since survey data was not computerized until 1983. Only the most recent survey on each

lake was entered at that time. There were, however, 901 surveys in the data base that were done before 1974. The earliest of these was conducted in 1951.

Variables identifying each survey and associated limnological variables were extracted from the lake survey data base for this study (Table 1). Measurement variables were examined for obvious errors and corrected. For example, if shoreline development (SDF) for a lake was calculated to be less than one, the reported measurement of lake area or shoreline length was wrong. Detected errors were corrected by contacting the appropriate Fishery Management Area for accurate information. Detected errors found were usually typographical and were often misplaced decimals.

Additional variables describing physical characteristics of the lakes were derived from the data base. These include: shoreline development (SDF); area: shoreline length ratio; and lake volume (maximum depth /3 X lake area). Frequency distributions of each measurement variable were examined and data transformations were made where indicated. Distributions of physical variables were normalized using natural logarithms. Chemical variables or those related to water chemistry (secchi disc transparency) were normalized using square root transformations.

Survey gill and trap net catches of 28 fish species were included (Table 2). Gill and trap net specifications have been constant since 1951 except that nylon webbing replaced cotton or linen during the 1960s. Netting effort increased with lake size (Moyle 1950; Moyle and Lound 1960). Total numbers and pounds of each species caught, and number of lifts for each gear type were used to calculate mean CPUE (catch per unit effort) for each survey. Mean weights for each species and gear type were calculated. Obvious errors in reported net catches were detected and corrected. Calculation of a mean weight of 60 pounds for bluegill is an example of an obvious error. Distributions of mean catches and mean weights were normalized using natural logarithms.

Statistical Analysis

Only eight of the transformed or derived physical and chemical variables were available for most lakes (74%) in the data base. These were: area, maximum depth, percent littoral, total alkalinity (TA), secchi disc transparency, SDF, lake volume, and area:shoreline ratio. Lakes with several surveys were used only once in the analysis. Secchi transparencies and TA from multiple surveys of specific lakes were averaged.

Table 1. Physical and chemical variables in the lake survey data base used for this study.

Fishery Management Area	Lake area (acres)
Watershed	Maximum depth (ft)
Lake Identification Number	Median depth (ft)
Date of survey	Percent littoral
Extent of emergent vegetation	Shoreline length (mi)
Max. depth, submerged vegetation	Longest length (mi)
Thermocline beginning (ft)	Bottom soil types
Thermocline depth (ft)	Secchi transparency (ft)
Outlet flow (cfs)	Total alkalinity (ppm)
Water level fluctuations (ft)	pH
Annual	Total phosphorous (ppm)
Long-term	Total nitrogen (ppm)
	TDS (ppm)

Table 2. Common and scientific names of fish species included in this study, and codes used to identify them. See Figure 8.

Common name	Code	Scientific name
Bowfin	BF	*Amia calva*
Cisco	TU	*Coregonus artedi*
Lake whitefish	WF	*Coregonus clupeaformis*
Lake trout	LT	*Salvelinus naymaycush*
Northern pike	NP	*Esox lucius*
Muskellunge	MU	*Esox maxquinongy*
Carp	CA	*Cyprinus carpio*
Golden shiner	GSH	*Notemigonus crysoleucas*
White sucker	WS	*Catostomus commersoni*
Bigmouth buffalo	BMB	*Ictiobus cyprinellus*
Shorthead redhorse	RH	*Moxostoma macrolepidotum*
Black bullhead	BLB	*Ameiurus melas*
Yellow bullhead	YB	*Ameiurus natalis*
Brown bullhead	BRB	*Ameiurus nebulosus*
Burbot	BUR	*Lota lota*
White bass	WB	*Morone chrysops*
Rock bass	RB	*Ambloplites rupestris*
Green sunfish	GSF	*Lepomis cyanellus*
Pumpkinseed	PS	*Lepomis gibbosus*
Bluegill	BG	*Lepomis macrochirus*
Smallmouth bass	SMB	*Micropterus dolomieu*
Largemouth bass	LMB	*Micropterus salmoides*
White crappie	WC	*Pomoxis annularis*
Black crappie	BC	*Pomoxis nigromaculatus*
Yellow perch	YP	*Perca flavescens*
Sauger	SAU	*Stizostedion canadense*
Walleye	WA	*Stizostedion vitreum*
Freshwater drum	FWD	*Aplodinotus grunniens*

Length of the growing season was estimated for each lake as the number of days between the beginning of late spring and the beginning of late fall, and used in later analyses. Baker and Strub (1963) defined the beginning of late spring as the time when less than 20% of the minimum temperatures are 32°F or lower. They defined the beginning of late fall as the time when more than 10% of the minimum temperatures are 32°F or lower.

Principal component analysis (Pielou 1984; Weisberg 1985) was performed using the nine variables listed above for 3,029 lakes. The analysis indicated that three components would explain 78.7% of the variance among lakes. Variables related to lake size (area, volume, area:shoreline ratio) accounted for 39.2%; variables related to depth (maximum depth, percent littoral, secchi transparency) for 24.3%; and total alkalinity, SDF, and growing season for the remaining 15.2%.

Each pair of the transformed variables was examined for colinearity. Relationships between total alkalinity and lake area, maximum depth, and secchi transparency were non-linear. Separating lakes in the three

northeastern counties of Cook, Lake, and St. Louis from lakes in the rest of Minnesota eliminated significant non-linearity between total alkalinity and the other three variables. Lake basins in the northeastern counties were formed mainly through scouring of Precambrian rock by glacial ice sheets (Schwartz and Thiel 1954). Lakes throughout the rest of Minnesota were formed mainly by the deposition of glacial debris. Moyle (1956) pointed out the differences in water chemistry resulting from the different glacial histories.

A second division of the lakes was made based on an examination of the distribution of percent littoral (Figure 1). The distribution is nearly normal from 0 to 80% littoral. The number of lakes increases from 80 to 100% littoral. The division of lakes into groups < 80% littoral and ≥ 80% littoral is an approximate separation of lakes that rarely or never winter-kill from those that frequently winter-kill.

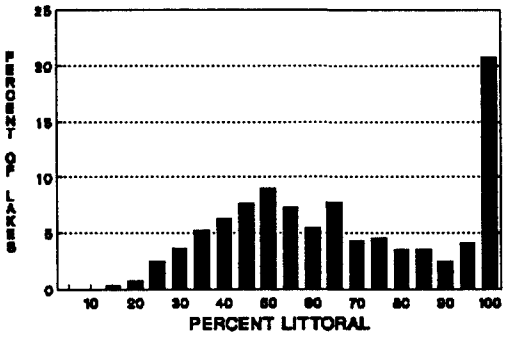

Figure 1. Frequency distribution (%) of percent littoral area for 3,029 classified lakes.

Thus all further analyses were done on four groups of lakes: high and low littoral zone lakes in northeastern Minnesota; and high and low littoral zone lakes in the rest of Minnesota. A k-means cluster analysis (Davis 1986) was performed on each of the four groups of lakes using the nine variables. The final choice of k was based on a comparison of the results of analyses using several values of k for each group.

The success of the four cluster analyses was evaluated using discriminant analysis. The nine variables used for clustering were reduced to seven through step-up regression. Variables eliminated were highly correlated such as area, maximum depth, and lake volume or area, SDF, and area:shoreline ratio. Only one or two variables from each of the above groups was retained for further analysis based on F-ratios. Thus seven variables were used in the discriminant analysis for each of the four lake groups.

Linear discriminant functions were used to assign each lake to a predicted class. The assigned classes were cross-tabulated with the results from cluster analysis. Final classification of each of the four groups of lakes was accepted when the percent reduction in classification error exceeded 90% of that expected if the lakes had been randomly classified.

Lakes in Koochiching, Itasca, and Carlton counties which border on St. Louis County were analyzed with both geographic groups. Results of this dual analysis determined into which of the two geographic groups these lakes were ultimately placed.

Gains resulting from the classification were evaluated by comparing the sums of squares (SS) due to classification to the Total SS from a General Linear Model ANOVA. This was done for six limnological variables, and for CPUE and mean weights of several species of fish in gill and trap nets. The results were also compared to a similar analysis using the original ecological classification (Scidmore 1970) for Minnesota lakes.

The Morphoedaphic Index (MEI) (Ryder 1965) and Carlson's Trophic Status Index (TSI) (Carlson 1977) were calculated for each lake. Total dissolved solids were estimated using the equation:

$$TDS = 28.83 + 1.2098\ TA \text{ ppm.}$$

The slope of this equation is nearly the same as that estimated by Ryder (1964) but the intercept is about 5 units larger. Carlson's TSI was estimated from secchi disc transpar-

ency. The lake classes were numbered in order of increasing MEI.

Lake Classification

The classification resulted in 44 lake classes among four groups:

< 80% littoral	≥ 80% littoral
Northeastern Minnesota	
11	8
Other Minnesota	
15	10

Lake Classes 1 through 19 lie mainly in the three northeastern counties and most are soft-water lakes (Table 3). Class 11, which contains abandoned iron-ore mine pits, and Class 19 are the only hard-water classes in northeastern Minnesota. The remaining Classes (20-44) are mainly hard-water lakes. The exceptions are Classes 20, 21, and 37 which average less than 50 ppm total alkalinity.

Lake Class numbers increase approximately from northeast to southwest within the state with increasing productivity (MEI) (Figure 2). Moyle (1956) pointed out the general increase in water fertility on a northeast-southwest axis, and concomitant increases in standing crops of fishes.

In a statistical sense, the goal of the classification was to reduce variation among lakes within classes. The classification succeeded in that endeavor (Table 4). The SS due to classification for six limnological variables ranged from 56.0 to 88.9% of the total SS. The greatest reductions were for physical variables. The smallest reduction was for secchi disc transparency which varies seasonally.

The lake classification also resulted in gains in relation to the original ecological classes (Scidmore 1970) (Table 4). The reduction in SS due to classification ranged from 45 to 146% higher than the earlier classification for six variables. The greatest reductions were for lake area and secchi disc transparency.

Similar reductions in SS due to classification were observed for 145 lakes not included in the original analysis but classified later (Table 5). The reduction in SS due to classification for lake size in this group was 56.7% compared to 80.0% for the original analysis. The range of lake sizes was not as great in this group since the largest lakes had already been classified.

Evaluation of Net Catches

Net catches are highly variable while mean sizes are less variable due to net selectivity. The reduced variation of limnological characteristics among lake classes was associated with significantly reduced variation of numbers and sizes of 23 fish species caught in lake survey gill or trap nets (Tables 6 and 7).

Effects of Classification

Based on F-ratios, the most significant reductions due to classification were for black bullhead *Ameiurus melas* in both net types (Table 6). The lake class SS for black bullhead accounted for 30 and 24% of the total for gill and trap nets, respectively. Black bullhead abundance increases markedly with increased eutrophication (Figure 3). The results for black crappie *Pomoxis migromaculatus* were similar. Classification accounted for 23.0 and 19.5% of the variation in gill and trap nets. Black crappie abundance also increases with increased eutrophication (Figure 4). White sucker *Catostomus commersoni* reached their highest abundance in Lake Classes 1-19, the rocky lakes of the Precambrian shield (Figure 5). The classification accounted for 25.6% of the total SS for gill net CPUE of suckers. The median percentage reduction in CPUE SS due to classification was 20.0% for gill and 10.3% for trap nets. SS of total biomass of all species per net lift were reduced 23.2% for gill and 28.4% for trap nets. Total biomass per net increased in general from oligotrophic through hypereu-

Table 3. Mean values of selected physical and chemical parameters for 44 Lake Classes. TSI is an abbreviation for Carlson's Trophic State Index.

Lake Class	Area, (A)	Maximum depth (Ft)	Littoral %	Total alkalinity	Secchi (Ft)	SDF	MEI	TSI
1	1,671	139.7	0.207	22.01	19.09	3.27	1.29	34.6
2	38,885	123.2	0.294	23.54	7.64	7.78	1.63	47.8
3	356	73.4	0.377	18.11	13.94	3.32	2.26	39.2
4	58	49.9	0.375	16.20	16.01	1.58	3.24	37.2
5	294	68.3	0.246	27.61	13.31	1.86	3.09	39.8
6	168	37.2	0.626	15.04	8.13	3.22	4.25	46.9
7	1,379	41.6	0.513	28.30	8.34	3.20	5.30	46.6
8	134	40.8	0.528	27.57	9.96	1.81	5.14	44.0
9	32	28.4	0.659	17.08	9.87	1.61	5.64	44.1
10	211	31.5	0.517	34.11	6.81	1.75	7.26	49.5
11	46	55.3	0.334	107.90	13.20	1.53	11.22	39.9
12	143	25.5	0.861	21.00	10.23	2.11	6.90	43.6
13	80	23.3	0.848	21.43	7.46	1.67	7.66	48.2
14	28	13.8	0.990	18.34	7.91	1.67	12.21	47.3
15	104	12.6	0.991	17.20	5.38	2.82	13.40	52.9
16	688	15.0	0.981	23.33	5.44	2.03	12.76	52.7
17	93	8.3	0.999	17.40	4.73	1.50	20.87	54.7
18	22	6.4	0.999	17.20	4.06	1.55	27.96	56.9
19	139	14.6	0.983	75.64	6.71	1.50	27.33	49.7
20	130	53.6	0.405	34.33	9.80	1.67	4.45	44.2
21	44	34.0	0.621	25.70	6.94	1.40	5.33	49.2
22	3,011	104.3	0.338	136.30	10.90	2.74	5.94	42.7
23	285	77.6	0.283	121.83	14.18	1.59	7.37	38.9
24	364	60.5	0.404	142.89	6.39	1.51	10.52	50.4
25	474	57.2	0.466	142.52	11.81	2.46	11.26	41.5
26	108,722	70.7	0.436	129.57	5.73	1.91	11.22	52.0
27	2,230	60.9	0.445	161.97	8.47	1.49	12.42	46.3
28	60	48.3	0.413	141.64	13.21	1.40	13.63	39.9
29	215	33.5	0.639	90.00	9.96	1.48	13.26	44.0
30	43	41.7	0.530	141.48	5.40	1.35	15.65	52.8
31	344	39.7	0.426	162.52	9.07	1.36	17.87	45.4
32	647	34.9	0.633	145.88	4.33	2.31	19.23	56.0
33	86	33.7	0.629	176.92	7.64	2.01	23.46	47.8
34	222	27.5	0.634	146.27	4.29	1.30	23.40	56.1
35	403	33.1	0.848	100.00	7.70	2.54	15.33	47.7
36	52	25.5	0.869	93.03	6.91	1.52	17.56	49.3
37	62	14.8	0.986	43.90	5.77	1.50	17.55	51.9
38	276	27.5	0.863	154.48	5.34	1.41	26.54	53.0
39	213	17.0	0.980	91.92	6.49	1.42	27.55	50.2
40	830	14.0	0.990	153.54	4.81	1.57	51.50	54.5
41	3,377	16.7	0.963	179.27	3.05	2.48	57.74	61.0
42	238	12.8	0.991	145.46	3.60	2.67	59.45	58.7
43	306	10.0	1.000	164.92	2.26	1.40	76.44	65.4
44	81	6.5	1.000	130.11	3.04	1.38	124.40	61.1

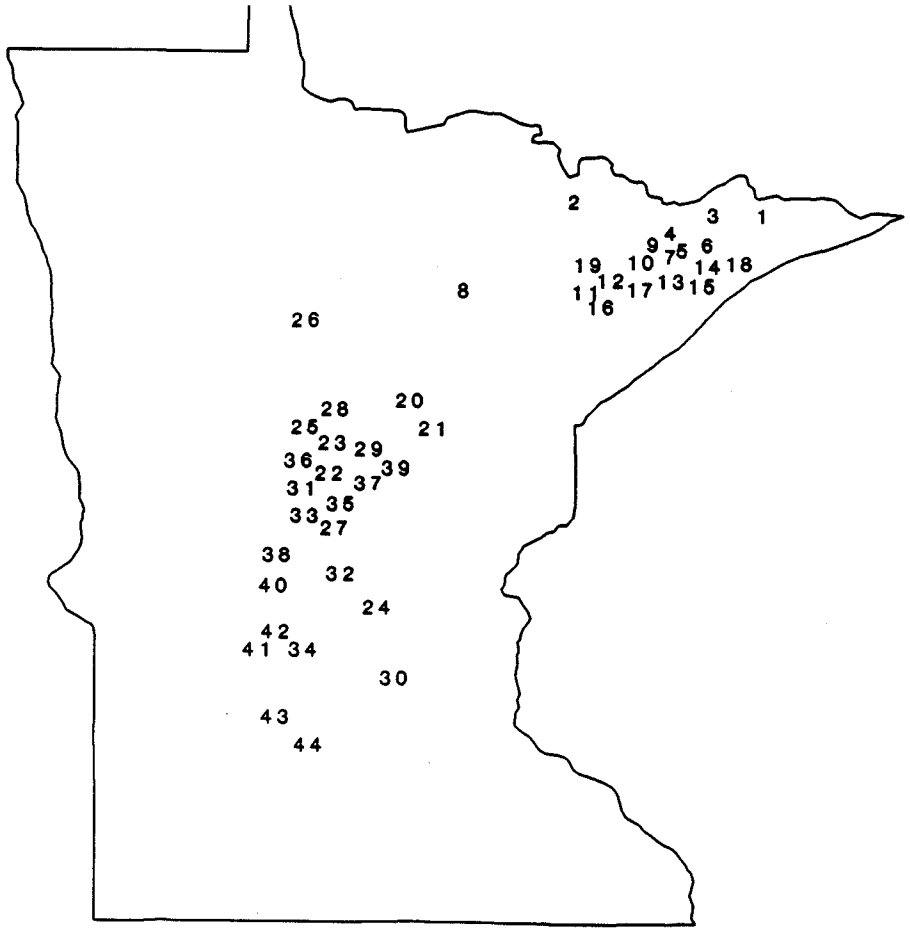

Figure 2. Approximate geographic centers of 44 lake classes.

trophic lake classes (Figure 6), reflecting increasing productivity.

The most significant reduction in variation of mean weights was for black bullhead in gill nets (Table 7). Classification accounted for 21.2% of the total SS for mean weight of black bullhead in gill nets. Reduction in SS for mean weight of trap netted black bullhead (13.1%) was among the higher reductions for that gear. The abundant populations of black bullhead in hypereutrophic lakes usually consist of small fish. Classification accounted for 22.8% of the total SS for mean weight of cisco *Coregonus artedi* in gill nets. Abundant populations of relatively small cisco occur in the Precambrian shield lakes of northeastern Minnesota. The median percentage reduction in mean weight SS due to classification was 11.2% for gill nets and 9.2% for trap nets.

Lakes Classified Later

Similar gains from classification for gill and trap net CPUE, and mean weights were observed in data from 263 lake surveys of 145 lakes classified after the original analysis (Tables 8 and 9). Significant reductions ($P < 0.05$) in total SS were achieved for CPUE of northern pike, white sucker and walleye, and for mean weight of white sucker and black and brown bullhead *Ameiurus nebulosus* in gill nets (Table 8). In trap nets, significant reductions were achieved for CPUE of carp *Cyprinus carpio*, black and yellow bullhead *Ameiurus natalis*, rock bass *Ambloplites rupestris*, and black crappie (Table 9). Significant reductions in trap net mean weights SS were achieved for bowfin *Amia calva*, rock bass, and pumpkinseed *Lepomis gibbosus*. Reductions in total biomass per lift in this sample were similar

Table 4. Summary of ANOVA results for six variables in relation to the classification of 3,029 Minnesota lakes and to the original ecological (Ecoclass) classification.

	Total df	Total SS	Lake Class SS	F	P	Ecoclass SS	SS Ratio Lake Class: Ecoclass
Area	3,028	5,862.5	4,570.7	245.62	< 0.001	1,855.4	2.46
Maximum depth	3,028	1,861.8	1,503.0	291.24	< 0.001	982.3	1.53
Littoral %	3,028	218.3	194.0	554.48	< 0.001	126.8	1.53
Total alkalinity	3,028	51,475.8	37,887.6	193.82	< 0.001	25,210.0	1.50
Secchi disc	3,028	2,139.1	1,198.9	88.64	< 0.001	610.9	1.96
SDF	3,028	365.3	211.9	95.99	< 0.001	66.4	1.45

Table 5. Summary of ANOVA results for six variables in relation to the lake classification for 145 Minnesota lakes classified after the original analysis.

	Total df	Total SS	Lake Class SS	F	P
Area	144	216.27	122.55	4.23	< 0.001
Maximum depth	144	116.00	90.67	11.69	< 0.001
Littoral %	144	11.10	9.54	19.62	< 0.001
Total alkalinity	144	2,439.04	1,598.20	5.98	< 0.001
Secchi disc	144	134.71	83.02	5.24	< 0.001
SDF	144	18.72	12.64	6.53	< 0.001

Table 6. Summary of ANOVA results of gill and trap net CPUE for 23 species of fish in relation to the classification of 3,029 Minnesota lakes and to the original ecological (Ecoclass) classification.

Species	Total df	Total SS	Lake Class SS	F	P	Ecoclass SS	SS Ratio Lake Class: Ecolass
			Gill nets				
LT	151	240.25	53.88	3.68	< 0.001	20.09	2.68
CS	1,121	2,577.30	310.71	4.13	< 0.001	148.74	2.09
WF	169	536.72	247.99	5.45	< 0.001	164.25	1.51
NP	4,949	5,118.61	760.65	19.91	< 0.001	406.91	1.87
MU	113	190.15	124.28	7.38	< 0.001	82.69	1.50
CA	663	1,715.73	275.98	5.33	< 0.001	180.76	1.53
WS	4,155	7,019.88	1,793.78	32.82	< 0.001	1,540.59	1.16
RH	288	493.93	154.87	3.30	< 0.001	95.60	1.62
BLB	2,642	11,447.39	3,431.60	30.14	< 0.001	2,030.22	1.69
YB	2,100	4,827.89	338.97	4.46	< 0.001	96.66	3.51
BRB	1,717	3,868.80	620.47	8.67	< 0.001	354.28	1.75
BUR	227	281.06	136.73	7.65	< 0.001	88.99	1.54
SMB	501	730.32	180.47	4.37	< 0.001	71.99	2.51
LMB	1,890	2,008.70	168.73	4.14	< 0.001	45.62	3.70
WC	378	979.41	91.85	1.76	0.021	25.58	3.59
BC	3,150	7,495.23	1,724.57	22.66	< 0.001	890.00	1.94
YP	4,637	12,677.54	1,293.06	12.13	< 0.001	841.64	1.54
WA	3,498	5,256.70	917.53	16.99	< 0.001	561.81	1.63
Lbs/ lift	2,737	5,294.72	1,229.24	40.04	< 0.001	396.78	3.10
			Trap nets				
BF	1,427	1,087.24	54.15	2.62	< 0.001	12.48	4.34
CA	1,005	1,891.56	295.61	7.57	< 0.001	184.45	1.60
BLB	2,484	11,984.32	2,877.22	19.81	< 0.001	1,694.61	1.70
YB	2,540	4,543.22	377.25	6.48	< 0.001	165.90	2.27
BRB	2,092	4,909.14	634.95	7.82	< 0.001	308.73	2.06
RB	1,558	2,008.92	239.67	4.77	< 0.001	64.51	3.72
GSF	880	1,888.32	142.66	2.03	< 0.001	20.70	6.89
PS	3,486	6,092.25	459.64	6.69	< 0.001	171.30	2.68
BG	3,858	10,637.54	1,100.08	10.74	< 0.001	676.20	1.63
SMB	236	353.74	103.77	2.65	< 0.001	57.82	1.79
LMB	2,432	2,742.14	179.45	4.08	< 0.001	36.80	4.88
WC	390	1,212.96	112.64	1.89	0.012	9.88	11.40
BC	3,427	8,317.46	1,621.07	19.51	< 0.001	673.88	2.41
Lbs/ lift	4,831	6,024.96	1,711.20	44.17	< 0.001	974.29	1.76

Table 7. Summary of ANOVA results of mean weights of 23 species of fish caught in gill or trap nets in relation to the classification of 3,029 Minnesota lakes and to the original ecological (Ecoclass) classification.

Species	Total df	Total SS	Lake Class SS	F	P	Ecological SS	SS Ratio Lake Class: Ecoclass
				Gill nets			
LT	146	108.51	7.93	0.97	0.479	0.56	14.16
CS	1,109	765.58	174.38	8.79	< 0.001	108.94	1.60
WF	160	90.71	20.82	1.77	0.023	4.09	5.09
NP	4,854	1,282.93	82.65	7.70	< 0.001	31.67	2.61
MU	112	52.32	20.58	2.65	< 0.001	7.18	2.87
CA	652	791.04	76.39	2.92	< 0.001	39.35	1.94
WS	4,050	1,246.73	93.58	7.56	< 0.001	35.83	2.61
RH	287	94.22	14.18	1.28	0.148	2.96	4.79
BLB	2,620	1,329.44	281.82	18.78	< 0.001	173.07	1.63
YB	2,092	610.26	76.78	8.46	< 0.001	38.95	1.97
BRB	1,710	706.20	108.03	8.17	< 0.001	67.96	1.59
BUR	221	152.31	47.49	3.55	< 0.001	22.20	2.14
SMB	495	254.92	28.57	1.66	0.012	9.32	3.07
LMB	1,878	1,087.53	42.10	1.80	0.001	5.34	7.88
WC	376	155.17	13.12	1.56	0.056	2.41	5.44
BC	3,132	1,463.30	146.51	8.39	< 0.001	57.22	2.56
YP	4,542	1,240.21	101.62	9.34	< 0.001	41.01	3.42
WA	3,453	1,540.58	140.44	7.95	< 0.001	94.83	2.83
				Trap nets			
BF	1,420	279.42	18.29	3.25	< 0.001	9.44	1.94
CA	988	717.64	57.09	3.47	< 0.001	28.22	2.02
BLB	2,469	1,267.19	165.92	9.39	< 0.001	96.31	1.72
YB	2,532	505.96	49.01	7.65	< 0.001	29.06	1.69
BRB	2,074	717.88	100.01	8.49	< 0.001	56.32	1.78
RB	1,542	498.90	50.14	3.99	< 0.001	27.64	1.81
GSF	867	431.59	31.64	2.00	< 0.001	1.50	21.09
PS	3,465	1,268.22	117.18	8.35	< 0.001	24.63	4.76
BG	3,840	1,565.38	75.72	4.71	< 0.001	24.42	3.10
SMB	233	147.15	32.05	1.75	0.011	6.72	4.77
LMB	2,425	2,484.23	107.16	2.62	< 0.001	36.99	2.90
WC	386	138.67	12.66	1.84	0.016	1.46	8.67
BC	3,409	1,335.98	131.24	8.73	< 0.001	36.49	3.60

Table 8. Summary of ANOVA results of gill net CPUE and mean weights of 9 species of fish in relation to the lake classification for 145 Minnesota lakes classified after the original analysis.

Species	Total df	Total SS	Lake Class SS	F	P
			CPUE		
CS	20	66.16	42.24	1.18	0.420
NP	151	149.14	56.29	2.55	< 0.001
WS	129	210.76	115.21	3.65	< 0.001
BLB	79	299.61	92.85	1.64	0.082
YB	38	107.16	42.08	1.40	0.227
BRB	41	120.34	49.54	1.21	0.323
BC	95	182.53	50.32	1.43	0.137
YP	147	279.03	82.88	1.46	0.074
WA	93	189.13	89.93	2.47	0.002
			Mean Weight		
CS	20	11.67	8.78	2.02	0.162
NP	151	32.63	7.85	1.33	0.143
WS	129	54.53	20.12	1.77	0.017
BLB	79	34.60	12.09	1.96	0.029
YB	38	11.52	2.91	0.73	0.708
BRB	41	12.75	7.18	2.23	0.035
BC	95	57.68	13.73	1.16	0.316
YP	146	44.70	11.35	1.16	0.274
WA	93	60.42	18.99	1.25	0.234

Table 9. Summary of ANOVA results of trap net CPUE and mean weights of 12 species of fish in relation to the lake classification for 145 Minnesota lakes classified after the original analysis.

Species	Total df	Total SS	Lake Class SS	F	P
			CPUE		
BF	32	19.06	5.18	0.71	0.714
CA	36	86.43	43.14	2.99	0.013
BLB	84	474.02	208.18	2.51	0.003
YB	54	98.61	54.28	2.45	0.011
BRB	59	121.39	47.44	1.73	0.078
RB	32	63.48	45.65	4.27	0.002
GSF	28	40.54	19.69	1.46	0.234
PS	111	197.75	46.92	1.13	0.333
BG	127	331.20	78.31	1.56	0.073
LMB	73	77.78	15.65	0.77	0.724
WC	17	61.67	35.31	2.46	0.093
BC	111	238.06	72.60	1.78	0.032
			Mean Weight		
BF	32	4.58	3.14	4.16	0.003
CA	36	37.22	13.24	1.66	0.149
BLB	84	49.37	15.40	1.45	0.132
YB	54	8.00	3.45	1.52	0.141
BRB	58	24.01	6.45	0.96	0.510
RB	32	16.75	10.61	2.88	0.018
GSF	28	14.42	4.19	0.63	0.778
PS	110	52.69	18.48	1.93	0.014
BG	127	56.11	7.55	0.78	0.733
LMB	73	77.96	15.92	0.78	0.709
WC	17	9.46	4.05	1.37	0.306
BC	110	42.77	11.59	1.49	0.100

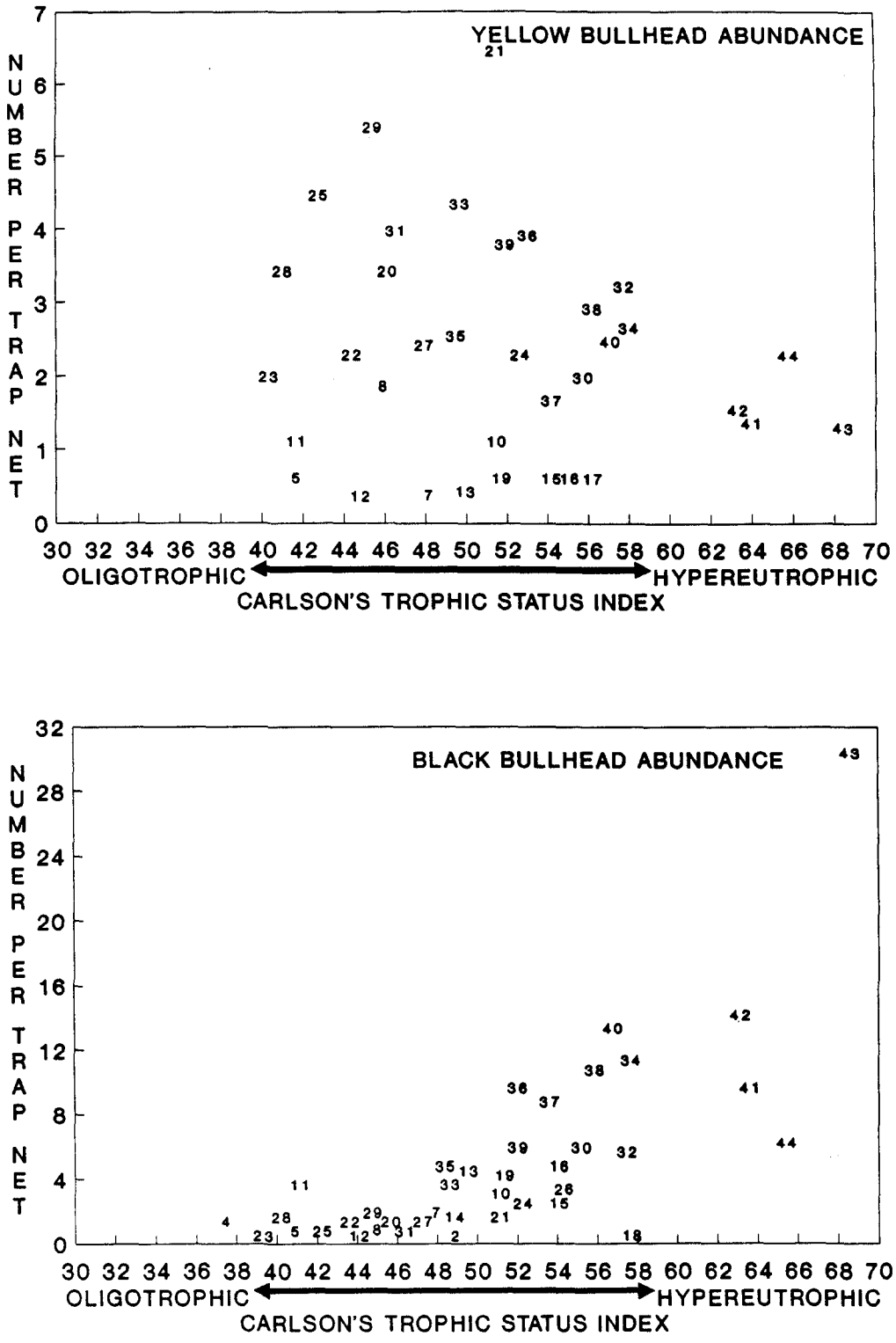

Figure 3. Median CPUE of yellow and black bullhead in lake survey trap nets for each lake class, and in relation to trophic status of the lake classes.

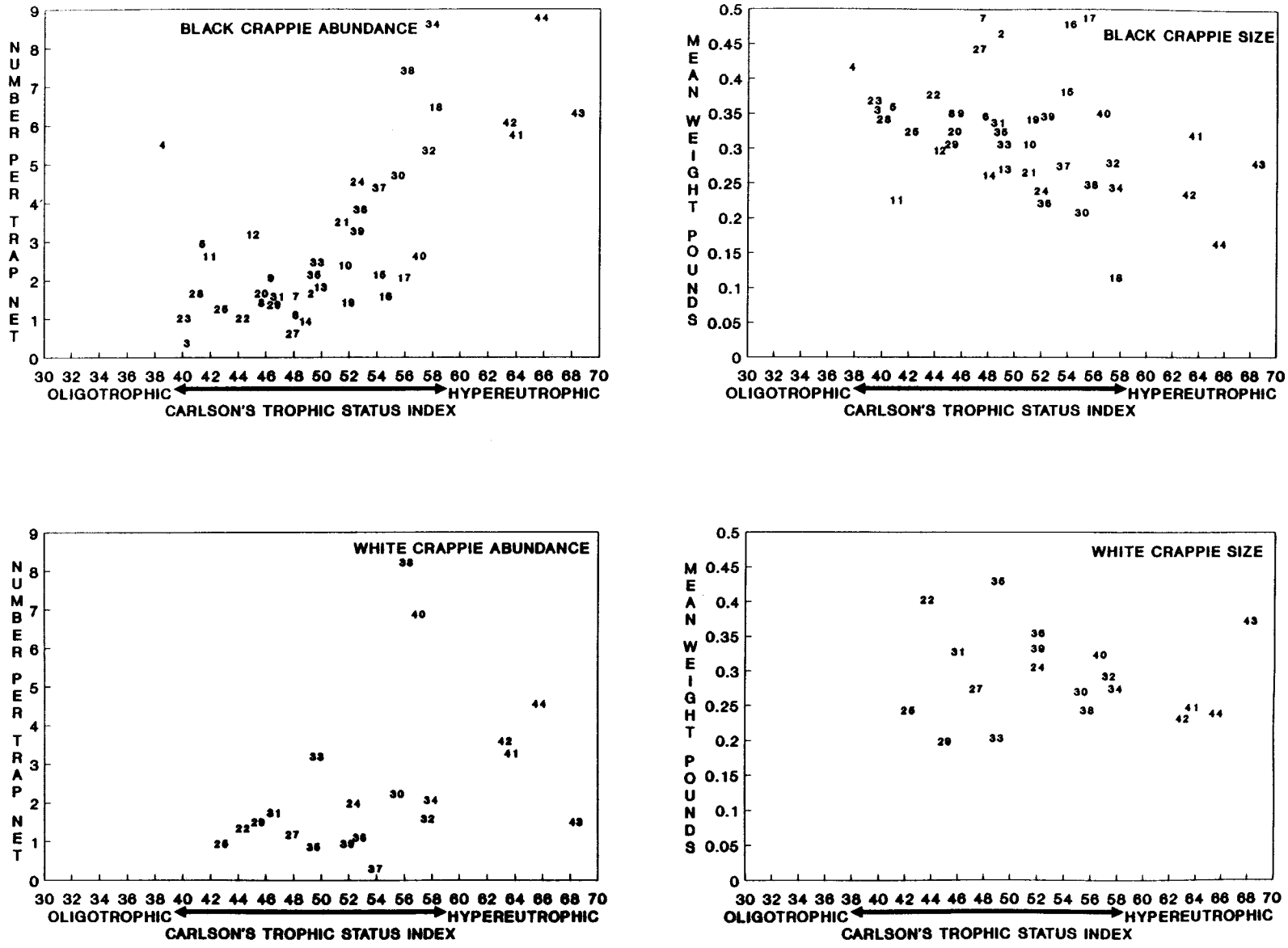

Figure 4. Median CPUE and mean weights of white and black crappie in lake survey trap nets for each lake class, and in relation to trophic status of the lake classes.

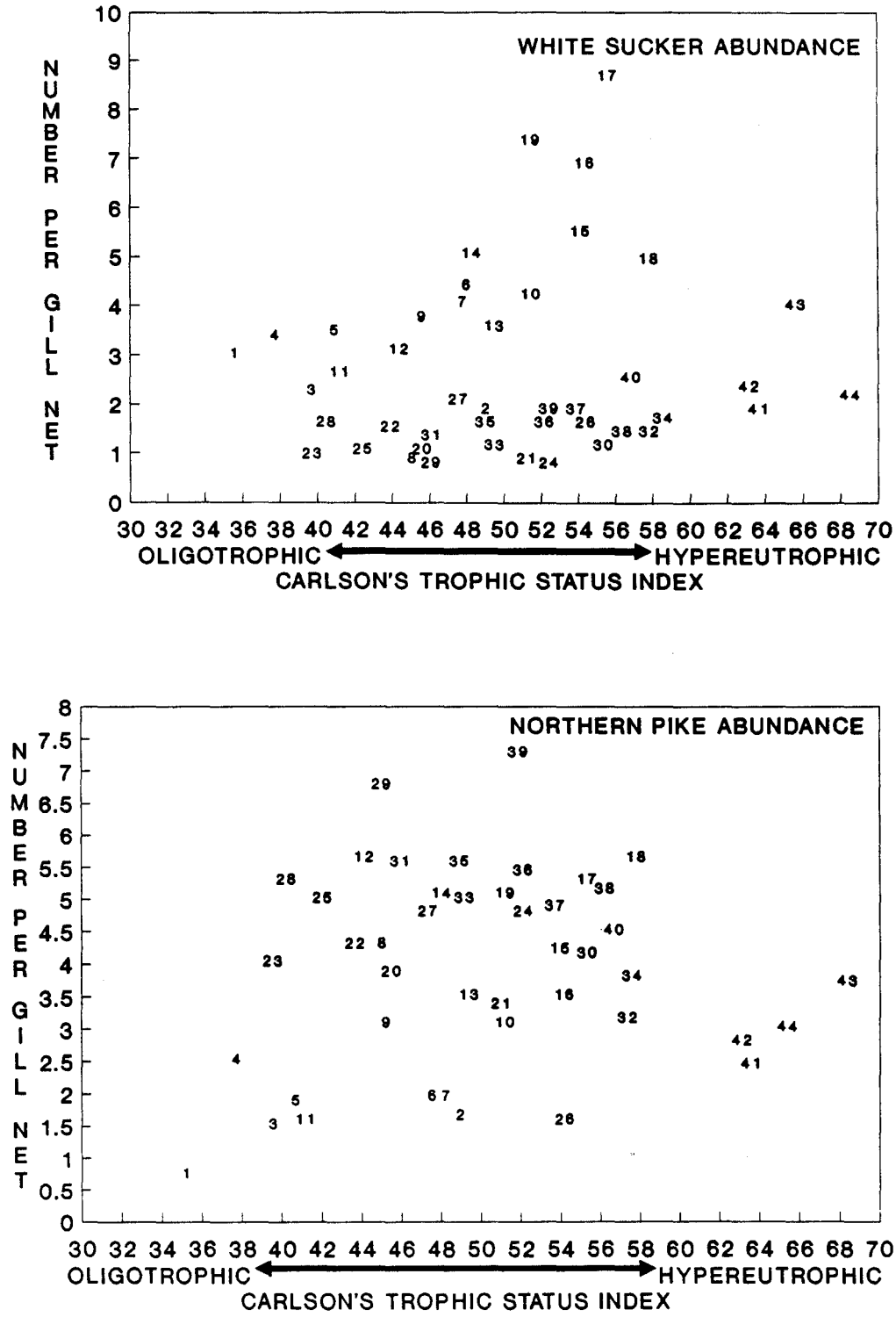

Figure 5. Median CPUE of white sucker and northern pike in lake survey gill nets for each lake class, and in relation to trophic status of the lake classes.

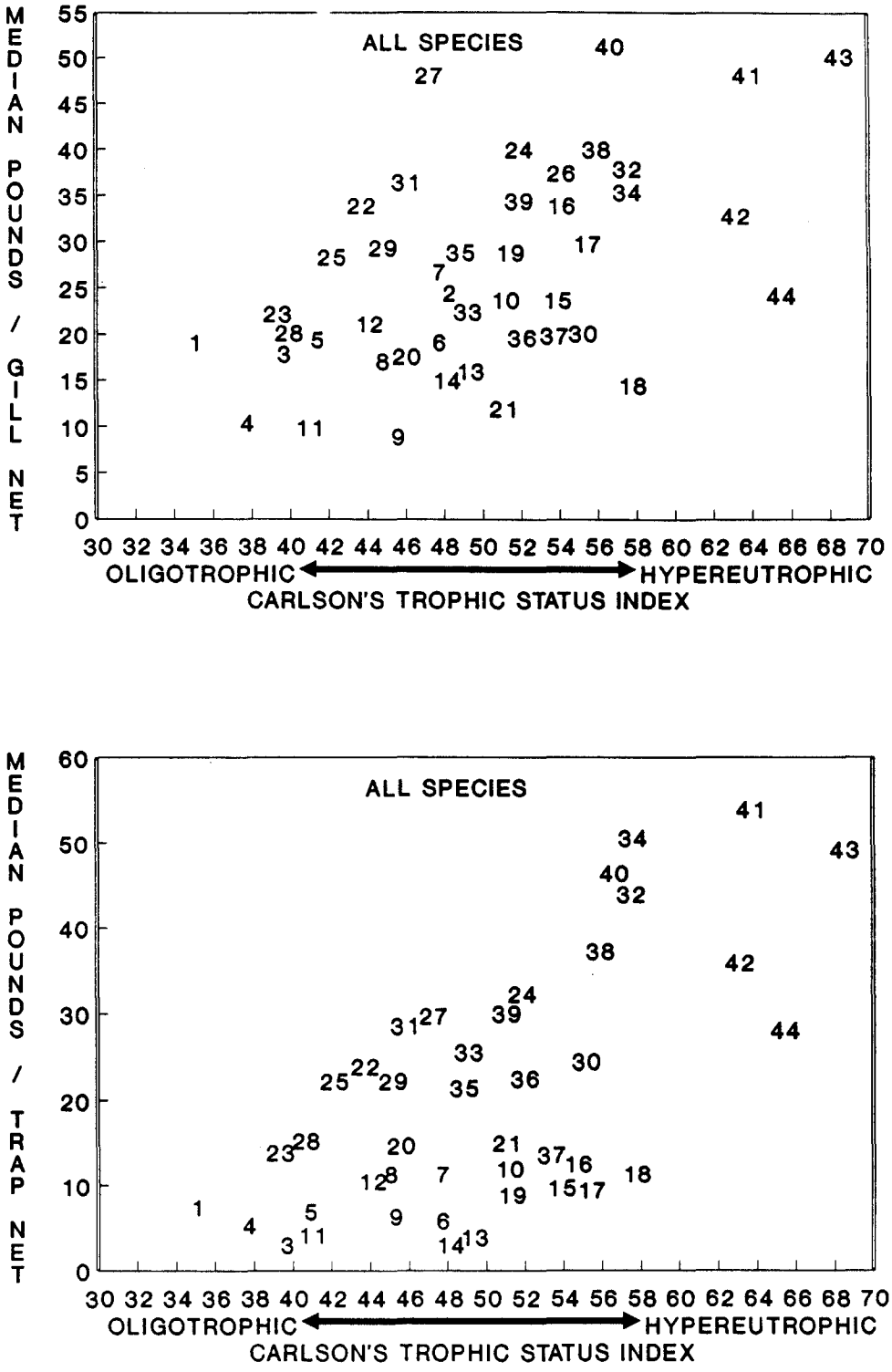

Figure 6. Median weight per gill and trap net in lake surveys for all species combined, and in relation to trophic status of the lake classes.

to those of the original classification, 25.1% for gill nets and 35.7% for trap nets.

Comparison to Earlier Classification

The lake classification also resulted in reductions in variation of net CPUE and mean weights when compared to the older ecological classification (Scidmore 1970) (Tables 6 and 7). The median reduction in total SS, expressed as a percentage, over the ecological classification was 72 and 141% for gill and trap net CPUE, respectively (Table 6). The median reduction in SS for mean weights was 185% in gill nets and 190% in trap nets (Table 7). SS for total biomass per net lift was reduced by 210 and 76% for gill and trap nets, respectively.

The largest gains in gill net CPUE were for lake trout, yellow bullhead, smallmouth and largemouth bass *Micropterus salmoides*, and white crappie *Pomoxis annularis*. The largest gains in trap net CPUE were for bowfin, rock bass, largemouth bass, and white and black crappie. Catches of yellow bullhead and both crappie species were strongly related to water clarity. Yellow bullhead catches were highest in relatively clear water (Figure 3) while crappie catches were highest in turbid water (Figure 4). The other centrarchid species listed above are also likely favored by clear water. Lake Class 1 (Table 3) comprises most of the lakes with lake trout present and is also the lake class with the clearest water. Water clarity was not among the variables used in the earlier ecological classification (Scidmore 1970).

Despite the gains for largemouth bass in both gears, evaluating bass abundance with netting surveys is still questionable. Reductions in SS due to classification for largemouth bass CPUE was 8.4% in gill nets and 6.5% in trap nets. These were among the lowest observed reductions.

The smallest gain in CPUE (16%) was for white sucker in gill nets. Many northeastern Minnesota lakes, where suckers are most abundant, were contained in two classes of the earlier system. Sucker abundance was apparently reflected nearly as well by that system as by the newer classification.

The largest gains in gill net mean weight were for lake trout, lake whitefish, shorthead redhorse *Moxostoma macrolepidotum*, largemouth bass, and white crappie. The largest gains in trap net mean weights were for green sunfish *Lepomis cyanellus*, pumpkinseed, smallmouth bass, and white and black crappie. No ready explanation, such as water clarity, suggests itself for these gains.

The difficulty in evaluating the status of largemouth bass populations by netting surveys was also evident in this analysis (Table 7). There was an increase in mean weight SS due to classification of 688% for gill nets, and 190% for trap nets over the earlier classification. The lake class SS, however, accounted for only 3.9 and 4.3% of the gill and trap net total SS, respectively. These were the lowest for any species in either gear.

Evaluation of Individual Surveys

Since lake classification usually accounted for less than 30% of the total SS for CPUE and less than 20% for mean weight, most of the variation in CPUE and mean weight remains unexplained. Medians and inter-quartile ranges for CPUE and mean weights of northern pike and walleye for selected lake classes are presented (Figure 7). The range of catches and sizes is high for some lake classes but quite low for others.

Inter-quartile ranges can be used as benchmarks for quick evaluations of survey net catches. Three examples of the use of inter-quartile ranges to evaluate survey catches are presented (Table 10). The first example, Knife Lake, is a case where drastic changes in community structure occurred between surveys. The second example, Big Sand Lake, is a case where the fish community has varied little over nine years. Big Spunk Lake is an example of a lake classified (Lake Class 31) after the analysis reported here. Survey net catches were com-

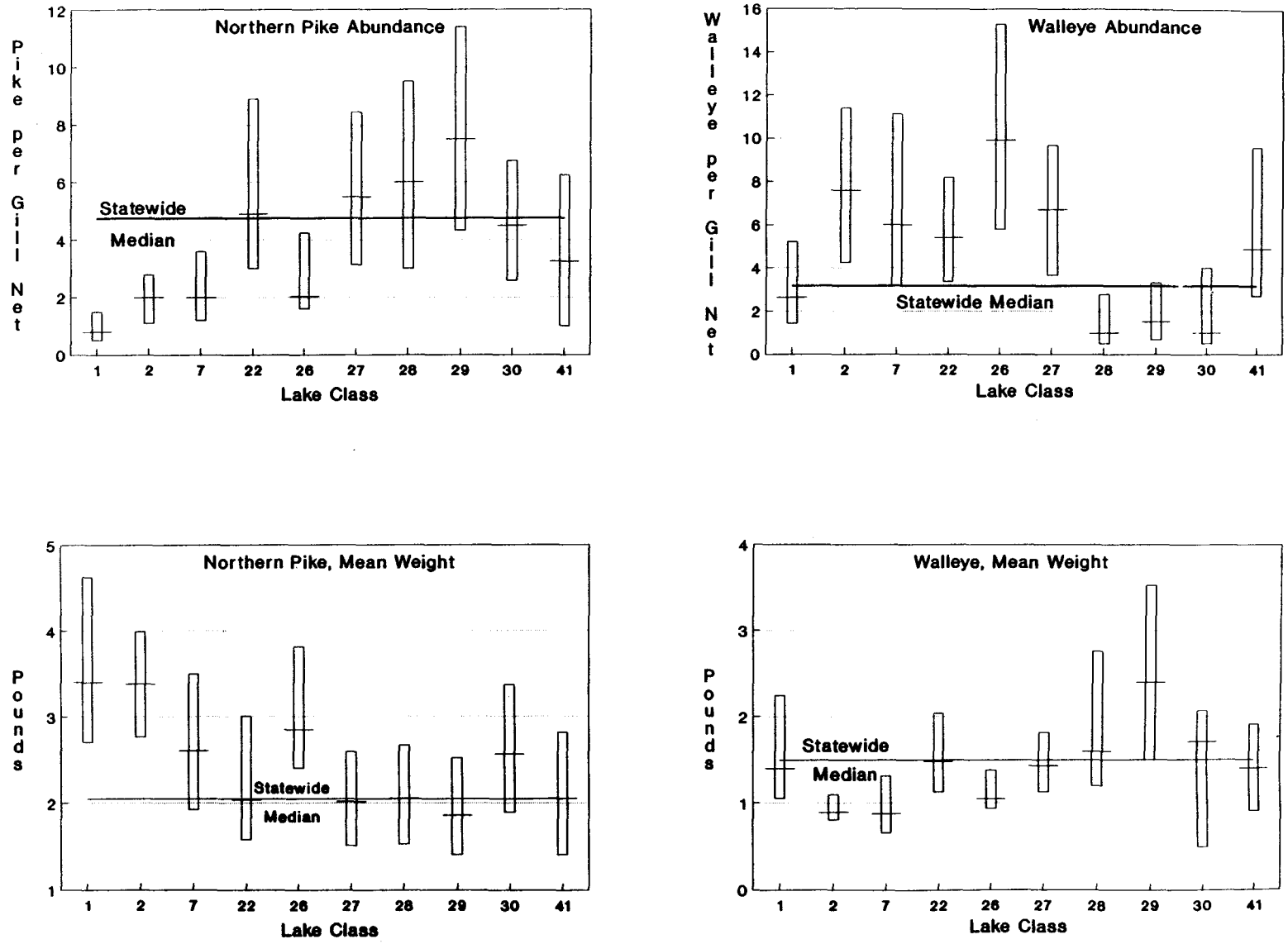

Figure 7. Intra-class medians, inter-quartile ranges, and the statewide median of northern pike and walleye CPUE, and mean weights for selected lake classes.

Table 10. Mean CPUE and mean weight (pounds) of selected species from recent lake surveys of Knife Lake, Kanabec County, Big Sand Lake, Hubbard County, and Big Spunk Lake, Stearns County, and inter-quartile ranges of these variables for all surveys for the appropriate Lake Class. Values lying outside inter-quartiles are in bold type.

Species	Gear	CPUE Mean	CPUE Inter-quartile Range	Mean Weight	Mean Weight Inter-quartile Range
Knife (Lake Class 40)					
		1979 1985		1979 1985	
Northern pike	Gill	**11.25** **1.27**	2.11- 9.00	1.77 **3.96**	1.47-2.68
Carp	Gill	**32.87** **28.91**	0.45-12.67	**0.21** **0.99**	1.29-4.92
White sucker	Gill	2.62 **1.00**	1.50- 5.67	1.45 **0.65**	1.41-2.26
White crappie	Gill	1.12 **18.36**	0.38-17.67	0.26 0.21	0.13-0.30
Black crappie	Gill	2.62 **29.45**	1.00-17.33	0.38 **0.19**	0.20-0.38
Yellow perch	Gill	15.00 **0.09**	7.13-40.83	0.17 **0.40**	0.15-0.30
Walleye	Gill	**21.50** **0.45**	2.67-10.00	**0.95** **2.81**	1.03-2.11
All species (Pounds)	Gill	59.24 45.56	38.47-74.92		
Big Sand (Lake Class 23)					
		1978 1983 1986		1978 1983 1986	
Cisco	Gill	1.36 - **0.29**	0.58- 6.43	0.80 - 0.50	0.43-1.03
Northern pike	Gill	**1.00** **2.11** **1.71**	3.00- 8.00	**3.25** **4.70** **6.47**	1.58-3.01
White sucker	Gill	2.82 1.89 1.71	0.91- 3.14	**2.34** **1.41** **2.41**	1.50-2.25
Rock bass	Trap	**13.92** **4.47** 3.67	0.80- 4.07	0.29 **0.24** 0.30	0.28-0.53
Bluegill	Trap	**1.83** **1.07** **3.13**	3.27-42.83	0.19 **0.23** 0.20	0.11-0.22
Yellow perch	Gill	17.55 12.22 17.14	5.75-27.20	0.15 0.18 0.17	0.12-0.21
Walleye	Gill	7.00 4.11 **12.14**	3.38- 8.21	1.57 **1.07** 1.36	1.13-2.04
All species (Pounds)	Gill	**27.43** **22.26** 43.05	28.11-50.43		
All species (Pounds)	Trap	**8.21** **2.47** **3.24**	9.64-21.62		
Big Spunk (Lake Class 31)[a]					
		1987		1987	
Northern pike	Gill	7.17	3.45-10.50	1.85	1.42-2.74
White sucker	Gill	2.17	0.50- 2.83	1.73	1.70-2.46
Yellow bullhead	Trap	4.43	1.50-11.58	**0.32**	0.49-0.86
Green sunfish	Trap	**2.71**	0.25- 2.00	**0.07**	0.10-0.20
Pumpkinseed	Trap	**1.43**	2.50-10.40	0.15	0.13-0.23
Bluegill	Trap	**57.29**	11.71-55.00	0.16	0.13-0.23
Black crappie	Trap	**19.43**	0.56- 3.17	**0.24**	0.25-0.50
Yellow perch	Gill	13.00	4.50-37.17	0.10	0.10-0.18
Walleye	Gill	2.00	1.25- 5.33	2.13	1.19-2.90
All species (Pounds)	Gill	28.55	26.87-51.85		
All species (Pounds)	Trap	22.50	11.33-29.92		

[a]Big Spunk Lake was classified and surveyed after the original lake classification.

pared to inter-quartile ranges established before the lake was classified.

Catches of northern pike, carp, and walleye in the 1979 survey of Knife Lake were above the third quartile for lakes of Class 40. The mean weight of pike was normal (within the inter-quartile range), while carp and walleye were small (below the first quartile). Numbers and sizes of white sucker, white and black crappie, and yellow perch *Perca flavescens* were within normal ranges. By 1985, catches of pike, walleye, and perch had declined to less than the first quartile. Mean sizes were above the third quartile. Carp were still abundant and small. Catches of crappie had increased to levels above the third quartile and average size declined between surveys. Catches and sizes of suckers declined between surveys. Total weight of all species was within normal ranges for both surveys.

Big Sand Lake supports a typical percid community. The results of three surveys over nine years were fairly similar (Table 10). Net catches indicated low abundance of northern pike and bluegill, while abundance of suckers and perch were within normal ranges. Walleye catches were also within normal ranges for two of the three surveys, while rock bass catches were high for two surveys. Pike sizes were large while perch sizes were normal. Total weight of all species tended to be low for both gill and trap nets.

Catches and sizes of northern pike, white sucker, yellow perch, and walleye from Big Spunk Lake were within normal ranges for lakes of Class 31. Catches of green sunfish, bluegill, and black crappie were above the third quartile while the catch of pumpkinseed was below the first quartile. Mean weights of yellow bullhead, green sunfish, and black crappie were below the first quartile.

Fish Communities

Community structure among the lake classes varied (Figure 8). Assemblages dominated by white sucker and walleye, or white sucker and northern pike were most common in northeastern Minnesota. Piscivores were uncommon or low in abundance in some smaller northeastern lake classes.

Assemblages dominated by northern pike and walleye, or northern pike and bluegill were most common in the southwesterly lake classes (Figure 8). Generally, lake classes which consisted of large lakes (larger than 1,000 A) had a high component of percids while small lakes had a high component of centrarchids. As lake classes approached hypereutrophy, black bullhead were more common as a significant part of the community structure.

Abundances of some closely related species varied with trophic state of the lake. For example, yellow bullhead were most common in mesotrophic classes (Figure 3), and were associated with relatively clear water. Black bullhead were associated with more turbid waters. Black and white crappie abundances increased, and average sizes declined in the more eutrophic classes (Figure 4). Higher proportions of white crappie in relation to black crappie were also evident in the more eutrophic classes.

Figure 8 indicates several groups of lake classes with the same species assemblages. While the same species made up the highest percentage of biomass in sampling nets within these groups, total biomass and the abundances and sizes of several species varied considerably between lake classes (Table 11).

Lakes in Class 6 are deeper and have less littoral than Classes 15 and 16 and thus are less productive (Table 3). This is reflected in lower biomass per gill net lift and lower catches of northern pike and yellow perch (Table 11). The perch also averaged smaller than in the latter two lake classes. Lakes in Class 15 are smaller than those in Class 16. Catches of yellow perch and walleye were lower in Class 15 and the perch average size was smaller. Walleye reach their greatest abundance in large, shallow lakes (Scott and Crossman 1973).

Lakes in Class 8 are deeper, have less littoral, and have clearer water than those in

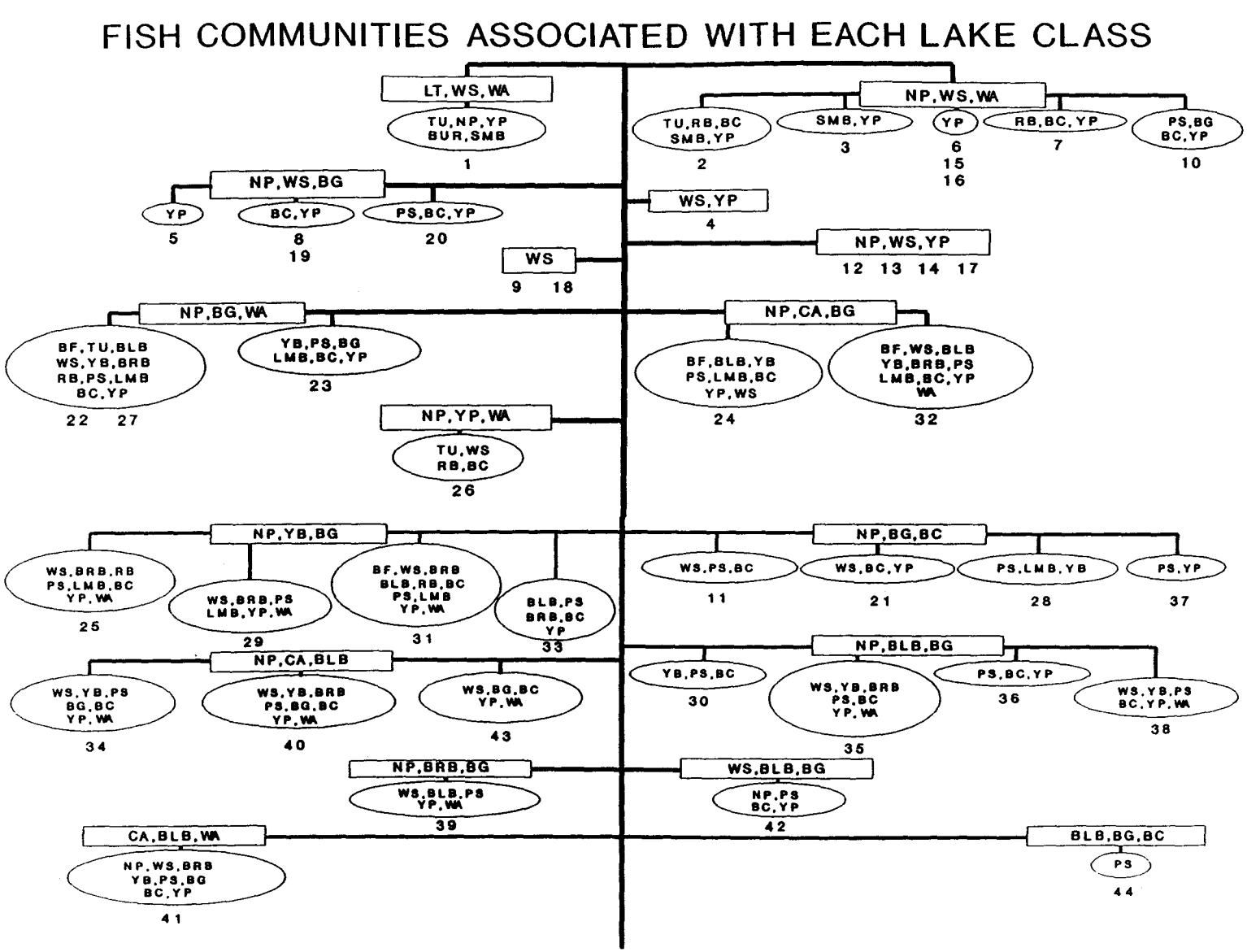

Figure 8. Fish assemblages associated with each lake class. One to three primary species, those making up the highest percentage of biomass in gill or trap nets, are indicated in rectangles. Secondary species (indicated in ellipses) were captured in at least 50% of the surveys.

Table 11. Differences in CPUE or mean weight (Lbs) of selected species in gill (G) or trap (T) nets for lake classes indicated to have similar community assemblages in Figure 8. All indicated differences are significant at $P \leq 0.05$ (t-test).

Lake		Total lbs/ lift	Northern pike		White sucker		Rock bass		Bluegill		Black crappie		Yellow perch		Walleye	
Class	Gear	All Species	No.	Lbs	No.	Lbs	No.	Lbs	No.	Lbs	No.	Lbs	No.	Lbs	No.	Lbs
6	G	20.2[ab]	1.9[ab]	2.2[b]	4.4[b]								1.8[ab]	0.14[ab]	3.5[b]	
15	G	26.0[c]	4.2										5.5[c]	0.19[c]	2.6[c]	
16	G	36.2	3.5	1.7	6.9								8.5	0.23	5.9	
8	G	16.5[d]			0.9[d]									0.13[d]		
19	G	30.1			7.4									0.17		
8	T								11.9[d]	0.17[d]						
19	T								2.9	0.27						
12	G	25.2[ef]	5.7[e]	2.1[fg]	3.1[g]									0.12[fg]		
13	G	13.5[i]	3.6[hi]	2.1[hi]	3.6[i]									0.14[i]		
14	G	14.2[j]	5.1	1.6	5.0[j]									0.16[j]		
17	G	23.2	5.3	1.6	8.6									0.20		
22	G	33.1[k]			1.5[k]								12.0[k]			
27	G	46.4			2.1								18.8			
22	T	13.0[k]					1.8[k]	0.30[k]			1.0[k]	0.36[k]				
27	T	18.6					1.2	0.36			0.6	0.44				

[a]Lake Class 6 differs from Lake Class 15

[b]Lake Class 6 differs from Lake Class 16

[c]Lake Class 15 differs from Lake Class 16

[d]Lake Class 8 differs from Lake Class 19

[e]Lake Class 12 differs from Lake Class 13

[f]Lake Class 12 differs from Lake Class 14

[g]Lake Class 12 differs from Lake Class 17

[h]Lake Class 13 differs from Lake Class 14

[i]Lake Class 13 differs from Lake Class 17

[j]Lake Class 14 differs from Lake Class 17

[k]Lake Class 22 differs from Lake Class 27

Class 19 (Table 3). The lower productivity of lakes in Class 8 is reflected in lower biomass per gill net lift than in Class 19 (Table 11). Bluegill abundance was higher in Class 8 while abundance of white sucker was higher in Class 19. Lakes in Class 19 are subject to periodic winterkill. Bluegill are probably less tolerant of low oxygen conditions than suckers and are also favored by greater water clarity.

Lake Classes 12, 13, 14, and 17 are similar in that they are small lakes that are mostly littoral (Table 3). Lakes in Class 12 tend to be relatively clear while those in Class 17 tend to be turbid. Biomass in gill nets was higher in Classes 12 and 17 than in the other two classes (Table 11). Catches of white sucker were higher in Class 17 lakes than in any other class (Figure 5). Yellow perch were relatively large in these lakes. Northern pike abundance averaged lower in Lake Class 13 than in the other three classes (Figure 5).

Lake Classes 22 and 27 are relatively large, hard-water lakes (Table 3). Lakes in Class 22 tend to be deeper, have clearer water, and the lake basins are more irregular in shape than those in Class 27. The higher productivity of lakes in Class 27 is reflected in higher biomass per lift for both gill and trap nets (Table 11). Abundances of white sucker and yellow perch were higher in Class 27 lakes. Abundances of rock bass and black crappie were higher, and average sizes smaller in Class 22 lakes.

Lake Classes 9 and 18 are indicated to be dominated by white sucker (Figure 8). These two classes consist of small lakes but differ in that lakes in Class 9 are deeper and have clearer water than those in Class 18. Suckers appeared in 52.3% of the surveys of Class 9 lakes and in 49.3% of the surveys of Class 18. No other species appeared in as many as one-half the surveys. Abundance of pike and suckers (Figure 5) were high for Class 18 lakes when they were present.

Discussion

The lake classification was successful in grouping lakes with similar morphoedaphic characteristics. Different community assemblages were associated with different lake classes. The advantage to fishery management is that successful management in one or a few lakes of a given ecological type should, in theory, have a higher probability of success in other lakes of that type. This concept has been described as "assessment by analogy" by Hoenig et al. (1987), and was implicit in the classifications reported by Johnson et al. (1977) and Tonn et al. (1983). Ontario explicitly formalized this concept in 1978 (Ontario MNR 1978). There is, however, no evidence that this management approach will succeed. Classification does provide a formal structure for testing the hypothesis.

The classification by Johnson et al. (1977) and Tonn et al. (1983) for Ontario lakes and for this study had similar goals, but started from opposite ends of the spectrum. Johnson et al. (1977) and Tonn et al. (1983) began by analyzing community structures, and then analyzing limnological variables associated with those structures. In this study, lakes were classified using limnological variables, while community structure associated with the classification were analyzed later.

Lake classification using limnological variables was chosen as a starting point because several species, particularly walleye and northern pike, have been widely stocked throughout Minnesota. Other human influences, especially agricultural practices, lakeshore development, and fishing have also altered community assemblages in many lakes. It was felt that the optimum fish communities for the different lake classes could be better delineated by classifying lakes by physical and chemical habitat rather than by community assemblage. The species most strongly associated with each lake class (Figure 8) are also those most likely to thrive under good fishery management practices.

Despite the opposite approaches taken by Johnson et al. (1977) and this study, there were some parallel results. Ontario

added brook trout and lake whitefish to the combination of species used by Johnson et al. (1977) (Ontario MNR 1978). This resulted in classifying Ontario's lakes into 63 community types (classes). Brook trout were a component of 32 of Ontario's community types, but are uncommon in Minnesota lakes. Minnesota does, however, have lake classes that appear to be ecological equivalents to lakes in Ontario that support brook trout. Lake trout were a component of 16 of the Ontario community types, but were a major component in only one of the Minnesota lake classes. Six of the remaining 15 Ontario community types had parallel community structures to those in the 19 northeastern Minnesota lake classes. These were mainly in northwestern Ontario where Minnesota shares a border of more than 350 miles.

Statistically significant reductions in variation of CPUE and mean weights of individual species in gill and trap nets were achieved through classification, but more than 80% of the variation was still unaccounted for in most cases. This should not be surprising since fish are not uniformly distributed in a lake. Estimates of abundance and size would also be influenced by varying year class strengths. Dolman (1990) reported improved precision of statewide C/f estimates from electrofishing surveys of 33-43% for bluegill, and 11-23% for largemouth bass as a result of reservoir classification. Seasonal effects on net CPUE and mean weights of captured fish are also evident in the Minnesota data base. Further analyses incorporating seasonal effects may improve the precision of CPUE and mean weight estimates.

Since the variation of catch indices within lake classes remains relatively high, the significance of changes can still be difficult to interpret. Moyle (1950), and Moyle and Lound (1960) recommended comparing mean catches for a survey to a statewide median and testing for statistical differences at the 80% probability level.

In practice, Minnesota fishery managers have usually compared mean catches to the appropriate statewide medians without regard to statistical significance. Management plans were often based on these comparisons. Statewide medians have some value, but are a poor standard for a given survey since they don't consider the influence of habitat on the observed catches. The failure to consider the statistical significance of any differences has probably led to many erroneous conclusions.

It is recommended here that survey net catches be compared to intra-class quartiles rather than to medians. Catches below the first quartile or above the third quartile for a particular lake class should be viewed as unusual, and meriting more detailed examination. Catches within the inter-quartile range can be viewed as normal for that lake type. Fishery managers should thus be able to identify possible problems rapidly from a lake survey, and focus their efforts on resolving them. This is particularly important where fishery managers are responsible for many lakes, but are able to assess their lakes only infrequently with brief, standardized lake surveys.

Use of quartiles to identify unusual net catches is a statistically conservative approach. It has the advantage of aiding rapid identification of gross departures from more typical catches, but is not a substitute for statistical testing.

The results of the Knife Lake surveys are an example of the potential value of using quartiles, not only to identify unusual catches, but to provide a framework for evaluating the catches and considering solutions. High catches of pike and walleye, such as those in 1979, are usually judged as favorable since these species are highly desired by anglers. Judging the catches by comparison to quartiles would have flagged these as unusual and a potential problem.

By 1985, the CPUEs of all seven species listed for Knife Lake (Table 10), and six of the seven mean weights were outside the inter-quartile ranges. One possible speculative cause of the changes observed between 1979 and 1985 is that the high populations of small to moderate piscivores may have

decimated the normal yellow perch population present in 1979. Perch is a preferred prey for both pike and walleye. Black and white crappie benefitted from the decline in perch, and may have affected recruitment of pike and walleye, leading to the low populations of large piscivores present in 1985. The true causes of the changes are unknown. This example does, however, illustrate how the use of quartiles can promote consideration of changes in the fish community and their causes. Knife Lake and its watershed was treated with rotenone in 1989 because of the changes in community structure.

In contrast, catches from Big Sand Lake indicated a relatively stable fish community. The unusual catches observed can probably be attributed to variations in year-class strengths, or may simply be the result of sampling errors.

Management Implications

The greatest value of organizing survey data as in Table 10 is that it forces viewing the results in the context of fish community structure. Analyzing the results from a holistic viewpoint rather than from the single species approach so common until now should lead to management recommendations that have a higher probability of success. The following set of simple questions is suggested as an outline for evaluating survey results and developing management plans:

1. Is the unusual catch (CPUE or size) a problem?
2. Do I want to do something about it?
3. Can I do something about it?
4. What are the possible consequences of a management action on the target species and on the associated fish community?
5. How will the results of the management action be evaluated?

The last two questions may be the most important, and are also the most likely to be overlooked or ignored. Evaluation of management actions, including the consequences on the aquatic community, should be axiomatic. Lack of evaluation leads to the continuing inertia of expensive management failures so common to management agencies (Lewis et al. 1987; Loftus 1987), or even worse, to the disruption or loss of valuable aquatic communities. Fishery managers must be aware that processes which alter community metabolism are difficult if not impossible to reverse once in operation (Colby et al. 1987).

The approach to evaluating survey results and management actions using quartiles as a first step is relatively simple and fast. Even those fishery managers who are burdened with the responsibility of too many waters should be able to quickly sort out their most pressing problems. Setting management priorities based on an evaluation of likely problems that can be solved should lead to a more rational use of the limited time and resources common to most fishery managers.

References

Baker, D.G., and J.H. Strub, Jr. 1963. Climate of Minnesota. II. The agricultural and minimum-temperature-free seasons. Minnesota Agricultural Experiment Station Technical Bulletin 245, St. Paul.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Colby, P.J., P.A. Ryan, D.H. Schupp, and S.L. Serns. 1987. Interactions in north-temperate fish communities. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2): 104-128.

Davis, J.C. 1986. Statistics and data analysis in geology. John Wiley and Sons, 2nd edition, New York.

Dolman, W.B. 1990. Classification of Texas reservoirs in relation to limnology and fish community associations. Transactions of the American Fisheries Society 119:511-520.

Eddy, S. 1938. A classification of Minneso-

ta lakes for fish propagation. Progressive Fish Culturist 41:9-13.

Hoenig, J.M., D.M. Heisey, W.D. Lawing, and D.H. Schupp. 1987. An indirect rapid methods approach to assessment. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2):324-338.

Johnson, M.G., J.H. Leach, C.K. Minns, and C.H. Olver. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye (*Stizostedion vitreum vitreum*), northern pike (*Esox lucius*), lake trout (*Salvelinus naymaycush*), and smallmouth bass (*Micropterus dolomieui*). Journal of the Fisheries Research Board of Canada 34:1592-1601.

Lewis, C.A., D.H. Schupp, W.W. Taylor, J.J. Collins, and R.W. Hatch. 1987. Predicting Great Lakes fish yields: tools and constraints. Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2): 411-416.

Loftus, K.H. 1987. Inadequate science transfer: an issue basic to effective fisheries management. Transaction of the American Fisheries Society 116:314-319.

Moyle, J.B. 1946. Some indices of lake productivity. Transactions of the American Fisheries Society 76:322-334.

Moyle, J.B. 1950. Gill nets for sampling fish populations in Minnesota waters. Transactions of the American Fisheries Society 79:195-204.

Moyle, J.B. 1956. Relationships between the chemistry of Minnesota surface waters and wildlife management. Journal of Wildlife Management 20(3):303-320.

Moyle, J.B., and R. Lound. 1960. Confidence limits associated with means and medians of a series of net catches. Transactions of the American Fisheries Society 89(1):53-58.

Ontario Ministry of Natural Resources. 1978. Designation of assessment units. Final Report of SPOF Working Group One, Toronto.

Pielou, E.C. 1984. The interpretation of ecological data: A primer on classification and ordination. John Wiley and Sons, New York.

Rawson, D.S. 1952. Mean depth and fish production of large lakes. Ecology 33:513-521.

Rounsefell, G.A. 1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia 1946(1):29-40.

Ryder, R.A. 1964. Chemical characteristics of Ontario lakes as related to glacial history. Transactions of the American Fisheries Society 93(3):260-268.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Transactions of the American Fisheries Society 94(3):214-218.

Schwartz, G.M., and G.A. Thiel. 1954. Minnesota's rocks and waters. University of Minnesota Press, Minneapolis.

Scidmore, W.J. 1970. Manual of instructions for lake survey. Minnesota Department of Conservation, Special Publication 1 (Revised), St. Paul.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184, Toronto.

Thompson, D.H. 1941. The fish production of inland streams and lakes. Pages 206-207 *in*: A symposium on hydrobiology. University of Wisconsin Press, Madison.

Tonn, W.M., J.J. Magnuson, and A.M. Forbes. 1983. Community analysis in fishery management: an application with northern Wisconsin lakes. Transactions of the American Fisheries Society 112: 368-377.

Weisberg, S. 1985. Applied linear regression. John Wiley and Sons, 2nd edition, New York.

United States Environmental Protection Agency

Office of Water
Mail code 4304T

EPA-822-R-21-005
August 2021

Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs



Office of Science and Technology

Office of Water

U.S. Environmental Protection Agency

Washington, DC

Notices

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Cover photo by Dana Thomas, 2019

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Executive Summary

Excess nutrients can degrade the condition of water bodies worldwide; in lakes and reservoirs (hereafter, referred to only as "lakes" unless noted otherwise), the effects of excess nitrogen (N) and phosphorus (P) may be particularly evident. High levels of nutrient loading commonly stimulate excess growth of phytoplankton, which can limit the recreational use of lakes. Overabundant phytoplankton also increase the amount of organic matter in a lake, which, when decomposed, can depress dissolved oxygen (DO) concentrations below the levels needed to sustain aquatic life. In extreme cases, the depletion of DO causes fish kills. Nutrient pollution can stimulate the excess growth of nuisance phytoplankton, such as cyanobacteria, which can produce cyanotoxins that are toxic to animals and humans. Elevated concentrations of cyanotoxins can reduce the suitability of a lake for recreation and as a source of drinking water.

Numeric nutrient criteria provide an important tool for managing the effects of nutrient pollution by providing nutrient goals that ensure the protection and maintenance of designated uses. The United States (U.S.) Environmental Protection Agency (EPA) published recommended numeric nutrient criteria for lakes and reservoirs in 2000 and 2001 for 12 out of 14 ecoregions of the conterminous United States. Those criteria were derived by analyzing available data on the concentrations of total nitrogen (TN), total phosphorus (TP), chlorophyll *a* (Chl *a*), and Secchi depth.

Scientific understanding of the relationships between nutrient concentrations and deleterious effects in lakes has increased since 2001, and standardized, high-quality data collected from lakes across the United States have become available. In this document, EPA describes analyses of these new data and provides models from which numeric nutrient criteria can be derived. The criterion models replace the recommended numeric nutrient criteria of 2000 and 2001 and are provided in accordance with the provisions of Section 304(a) of the Clean Water Act (CWA) (Title 33 of the *United States Code* [U.S.C.] § 1314(a)) for EPA to revise ambient water quality criteria from time to time to reflect the latest scientific knowledge. CWA Section 304(a) water quality criteria serve as recommendations to states and authorized tribes for defining ambient water concentrations that will protect against adverse effects to aquatic life and human health. The ecological and health protective responses on which the criterion models are based were selected by applying a risk assessment approach to explicitly link nutrient concentrations to the protection of designated uses.

The criterion models are nonregulatory, and this document describes the models and their inputs. States may use the recommended models to derive candidate nutrient criteria for each applicable designated use and, after demonstrating that the criteria protect the most sensitive designated use, adopt the criteria into their state standards. States may also modify the criteria to reflect site-specific conditions or establish criteria based on other scientifically defensible methods (Title 40 of the *Code of Federal Regulations* [CFR] 131.11(b)). The updated recommended CWA Section 304(a) nutrient criteria for lakes do not compel a state to revise current EPA-approved and adopted criteria, total daily maximum load nutrient load targets, or N or P numeric values established by other scientifically defensible methods. As part of their triennial review, if a state uses its discretion to not adopt new or revised nutrient criteria based on these CWA Section 304(a) criterion models, then the state shall provide an explanation when it submits the results of its triennial review (40 CFR 131.20(a)).

Following the risk assessment paradigm, EPA first defined water quality management goals for numeric nutrient criteria, and then defined assessment endpoints and metrics that are associated with achieving these goals and are sensitive to increased nutrient concentrations. The water quality management goals are articulated as designated uses in Section 101(a)(2) of the CWA (33 U.S.C. § 1251) (i.e., the protection and propagation of fish, shellfish, and wildlife [aquatic life] and recreation in and on the water). Another common designated use for lakes is to serve as drinking water sources. Excess loads of nutrients can lead to excessive growth of phytoplankton that can adversely impact designated uses in different ways, described below as assessment endpoints and metrics. EPA modeled stressor-response relationships using these endpoints and metrics to derive recommended numeric nutrient criterion models (Table 1).

Table 1. Summary of designated uses and associated measures of effect and exposure

Designated use	Assessment endpoint	Risk metric	Applicability
Aquatic life	Zooplankton biomass	Rate of change of zooplankton biomass relative to phytoplankton biomass	All lakes
Aquatic life	Cool- and cold-water fish	Daily depth-averaged DO below the thermocline	Seasonally stratified lakes with cool- or cold-water fish
Recreation	Human health	Microcystin concentration to prevent liver toxicity in children	All lakes
Drinking water	Human health	Microcystin concentration to prevent liver toxicity in children	All lakes

For aquatic life, EPA identified two assessment endpoints. The first endpoint is zooplankton biomass, and the risk metric is the slope of the relationship between zooplankton and phytoplankton biomass, which quantifies the degree to which energy produced by phytoplankton at the base of the food web is transferred to zooplankton and subsequently to higher trophic levels. When excess nutrients are available, phytoplankton biomass can increase at rates that exceed the capacity of zooplankton to consume. The threshold for the risk metric is one in which the rate of change of zooplankton biomass relative to phytoplankton biomass is approximately zero. This condition describes a lake in which the biomass of grazing biota (i.e., zooplankton) does not increase with increases in food (i.e., phytoplankton), and primary production at the base of the food web is weakly linked to production at higher trophic levels. This endpoint applies to all lakes in the conterminous U.S.

The second aquatic life endpoint is health and survival of cool- and cold-water fish, and the risk metric is the DO concentration in deep water that protects against mortality of these fish. Excess nutrients typically increase primary productivity, which then increases the amount of organic matter in a lake. Then, in the deep waters of a lake, DO is consumed as this organic matter is decomposed, leading to hypoxic and anoxic conditions. The risk metric is defined more specifically as the daily DO concentration, calculated as a depth-averaged value below the thermocline, which can be reduced to concentrations insufficient to support some fish species during the critical period of the summer when they require deep, cold waters to escape high temperatures at shallower depths. This endpoint applies to seasonally stratified lakes harboring cool- and cold-water fish.

For recreational uses and drinking water sources, the assessment endpoint is human health. For recreational uses, EPA selected the threshold for the risk metric as the concentration of microcystin associated with adverse effects on children (specifically, liver toxicity) from incidental ingestion of water during recreation. When excess nutrients are available, phytoplankton communities can shift toward a greater abundance of cyanobacteria that can release cyanotoxins, and microcystins are the most commonly monitored and measured freshwater cyanotoxin in the U.S. The threshold for the risk metric is 8 micrograms per liter (µg/L), based on recently published national recommendations for human health recreational water quality criteria and swimming advisories for cyanotoxins (US EPA 2019). For the drinking water use, EPA selected the threshold for the risk metric as the concentration of microcystins

associated with adverse effects on children resulting from oral exposure to drinking water (0.3 µg/L), consistent with the health advisory for microcystins (US EPA 2015b). The microcystin concentration from the health advisory applies to finished drinking water; however, EPA is aware that states and authorized tribes express water quality standards for protecting drinking water sources as either protecting the ambient source water before treatment or after treatment. The ability of treatment technologies to remove microcystin is too variable for EPA to set a national recommendation for an ambient source water concentration that would yield a protective concentration after treatment. If a state or authorized tribe applies the health advisory standard to drinking water after treatment, then they can account for the expected treatment in their facilities and select a higher microcystin concentration in the ambient source water that would result in the targeted microcystin concentration in the finished drinking water.

Data used in this analysis were collected in EPA's National Lakes Assessment (NLA), which sampled lakes across the conterminous U.S. in 2007 and 2012. Most of the sampled lakes were selected randomly so the resulting data represent the characteristics of the full population of lakes in the conterminous U.S. At each lake, standardized protocols were used to collect extensive measurements of biotic and abiotic characteristics.

This document describes statistical stressor-response models that relate Chl *a* concentrations to each of the risk metrics and that relate TN and TP concentrations to Chl *a*. A hierarchical Bayesian network is specified for each model to represent the effects of different variables on the relationship of interest. For example, microcystin is related to cyanobacteria biovolume, which is then linked to Chl *a* concentration. The models directly represent the processes that govern the relationships of interest and facilitate the use of other data sets in conjunction with data from EPA's NLA. When coupled with the targets for each response, the models provide candidate Chl *a*, TN, and TP criteria recommendations that states may then use with state risk management decisions to demonstrate they are protective of different designated uses. For lakes with multiple use designations, the states shall adopt criteria from these candidate criteria that protect the most sensitive use.

Models provided in this document are based on national data, but states often collect extensive data during routine monitoring. Incorporating local data into the national models can refine and improve the precision of the stressor-response relationships. In the appendices of this

document, EPA describes three case studies in which state monitoring data have been combined with national data, yielding models that can be used to derive recommended numeric nutrient criteria that account for both unique local conditions and national, large-scale trends.

1 Introduction and Background

Nutrient pollution, or the excess loading of nitrogen (N) and phosphorus (P), can degrade the conditions of water bodies worldwide, and in lakes the effects of nutrient pollution are often most evident. One visible consequence of nutrient pollution in lakes and reservoirs (hereafter, referred to only as "lakes" unless noted otherwise) is cultural eutrophication, an increase in primary productivity and algal abundance that increases the amount of organic matter in a water body (Smith et al. 2006, Smith and Schindler 2009). Decomposition of organic matter reduces dissolved oxygen (DO) concentrations in the water column, especially in deeper waters under stratified conditions. These hypoxic conditions are inhospitable to most aquatic species and reduce their ability to survive within a particular lake (Jones et al. 2011, Scavia et al. 2014).

Nutrient pollution also favors the growth of undesirable, nuisance phytoplankton (e.g., cyanobacteria), some of which produce cyanotoxins (Paerl and Otten 2013). Many species of cyanobacteria are superior competitors for light compared to other phytoplankton. Hence, in lakes with nutrient pollution, cyanobacteria can dominate by reducing the light available to other phytoplankton (Carey et al. 2012). A number of other mechanisms, including superior uptake rates for carbon dioxide and an ability to migrate vertically in the water column, also may explain the frequent occurrence of cyanobacteria dominance in eutrophic systems (Dokulil and Teubner 2000). Cyanobacteria dominance can interfere with the designated uses of a lake because cyanobacteria not only can form unsightly and odorous surface scums (reducing the aesthetic appeal of the lake for recreation) (Paerl and Ustach 1982), but also can produce cyanotoxins that can limit the use of the lake as both a source of drinking water and for recreation (Cheung et al. 2013). Many species of cyanobacteria are also less palatable than other phytoplankton to grazing organisms, and so, increases in cyanobacterial abundance can alter lake food webs and reduce the efficiency with which energy from primary production is transferred to higher trophic levels (Elser 1999, Filstrup et al. 2014a, Heathcote et al. 2016).

Nutrient pollution in lakes and resulting adverse environmental effects are widespread in the United States (U.S.). Nutrient pollution occurs in lakes of different sizes, in catchments with varying land uses, and in different climates. The U.S. Environmental Protection Agency (EPA) has long recognized the effects of nutrient pollution and has recommended that states and authorized tribes (hereafter, "states"), acting under their Clean Water Act (CWA) authorities,

adopt numeric nutrient criteria as one way to facilitate the management of these effects. A state's numeric nutrient criteria (1) provide nutrient goals to protect and maintain the designated uses of a water body (Title 33 of the *United States Code* [U.S.C.] § 1313(c)), (2) provide thresholds that allow the state to make accurate water quality assessment decisions (33 U.S.C. § 1313(d)), and (3) provide targets for restoration of water bodies that can guide waste load allocation decisions (33 U.S.C. § 1313(d)). To assist states and authorized tribes in deriving numeric nutrient criteria, EPA has published a series of technical support documents on methods for deriving criteria for lakes and reservoirs (US EPA 2000a), streams and rivers (US EPA 2000b), wetlands (US EPA 2008), and estuaries and coastal waters (US EPA 2001). A technical support document on using stressor-response relationships for deriving numeric nutrient criteria has also been published (US EPA 2010a). In 2000 and 2001, under its authority described in Section 304(a) of the CWA (33 U.S.C. § 1314(a)), EPA issued 12 documents that provided recommended numeric nutrient criteria for lakes, streams, and rivers in different ecoregions of the U.S. These criteria were derived by using available monitoring data to estimate the concentrations of total nitrogen (TN) and total phosphorus (TP) that were expected to occur in least-disturbed reference water bodies in different nutrient ecoregions.

In accordance with the provisions of Section 304(a) of the CWA, which directs EPA to revise ambient water quality criteria from time to time to reflect the latest scientific knowledge, EPA is issuing revisions to numeric nutrient criteria recommendations for lakes based on analyses of newly available, national-scale data and reflecting advances in scientific understanding of the relationship between excess nutrients and adverse effects in lakes. The criterion recommendations are models that generate numeric nutrient criteria based on national data and state risk management decisions. State data, if available, can be incorporated into the national criterion models to compute relationships that more accurately represent local conditions. In deriving these models, EPA uses a risk assessment framework (Norton et al. 1992; US EPA 1998, 2014) to identify assessment endpoints that relate directly to the water quality management goals for U.S. lakes specified by the CWA and that are sensitive to increased concentrations of N and P. Then, EPA uses stressor-response analysis to estimate relationships between increased N and P (estimated by measurements of TN and TP) and different risk metrics directly linked to the assessment endpoints (US EPA 2010a). National criterion models are provided for both TN and TP as the simultaneous control of both nutrients provides the most effective means of controlling the deleterious effects of nutrient pollution

(US EPA 2015a, Paerl et al. 2016). These stressor-response criterion models replace the ecoregion-specific nutrient criteria recommended previously for lakes,[1] which were derived using a reference distribution approach.

The remaining sections of this document are organized broadly according to the steps of risk assessment: (1) problem formulation, (2) analysis, and (3) characterization. The purpose of this document is to provide the technical details underlying the estimation of relationships between increased nutrient concentrations and different responses, as well as details regarding the derivation of numeric nutrient criterion recommendations using the national models. States may use these criterion models to derive candidate nutrient criteria and, after demonstrating that the criteria protect designated uses, adopt the criteria into their state water quality standards. States may also modify the criteria to reflect site-specific conditions or establish criteria based on other scientifically defensible methods (40 CFR 131.11(b)). For waters with multiple use designations, the state shall adopt criteria from the candidate criteria that support the most sensitive designated use (40 CFR 131.11(a)(1)). Water quality standards adopted by states are subsequently subject to review by EPA, pursuant to Section 303(c) of the CWA (33 U.S.C. § 1313(c)).

2 Problem Formulation

Problem formulation is the first step in a risk assessment, in which "…the problem is defined, and a plan for analyzing and characterizing risk is determined" (US EPA 1998). More specifically, during problem formulation, the management goals are articulated, assessment endpoints and risk metrics are selected, and conceptual models are specified that link stressors with assessment endpoints.

2.1 Management Goals

EPA focused on protecting uses that reflect management goals articulated in Section 101(a)(2) of the CWA (33 U.S.C. § 1251), which include maintaining conditions so different water bodies support aquatic life use (i.e., providing for the protection and propagation of fish, shellfish, and

[1] Ecoregional nutrient criteria for lakes and reservoirs (EPA 822-B-00-007, EPA 822-B-01-008, EPA 822-B-01-009, EPA 822-B-01-010, EPA 822-B-00-008, EPA 822-B-00-009, EPA 822-B-00-010, EPA 822-B-00-011, EPA 822-B-00-012, EPA 822-B-00-013, EPA 822-B-00-014, and EPA 822-B-01-011)

wildlife), recreation (i.e., providing for recreation in and on the water), and use of the water body as a source of drinking water. Under the CWA, it is a state's responsibility to designate uses for its waters, and many states have designated uses that provide for aquatic life and recreation uses. Some states have also designated waters as sources of drinking water. EPA focuses on aquatic life, recreation, and drinking water source because they represent uses that are particularly sensitive to increased concentrations of N and P. States can derive candidate nutrient criteria for each of the applicable designated uses in their lakes and, by comparing these criteria, identify the most sensitive use. Water quality criteria adopted by states for waters with multiple use designations must support the most sensitive use (40 CFR 131.11(a)).

2.2 Assessment Endpoints and Risk Metrics

The next step in problem formulation is to define assessment endpoints that can be used to quantify attainment of the management goals. Each of the management goals expressed in terms of different designated uses was associated with different assessment endpoints. Protection of recreational uses and drinking water sources pertains to public health rather than ecological health, and hence, the assessment endpoint is human health for these two designated uses. For aquatic life, the procedures of ecological risk assessment were followed to select assessment endpoints defined as "explicit expressions of the actual environmental values that are to be protected" (US EPA 1998). Three considerations guided the selection of these endpoints: ecological relevance, susceptibility to the stressor of interest (i.e., increased nutrient concentrations in the present case), and relevance to management goals.

After selecting the assessment endpoints, EPA developed conceptual models that represented current understanding of the linkages between increased N and P concentrations and effects on the assessment endpoint and management goals (Figure 1). The conceptual models were used to select specific risk metrics that quantified key steps along the causal path linking increased N and P concentrations to deleterious effects on aquatic life and public health. The final selections for the criterion recommendations were also influenced by the availability of data at the continental spatial scales considered in this analysis. These risk metrics were used as the response variables in stressor-response analysis. For a narrative description of the conceptual model, refer to *Using Stressor-Response Relationships to Derive Numeric Nutrient Criteria* (US EPA 2010a).

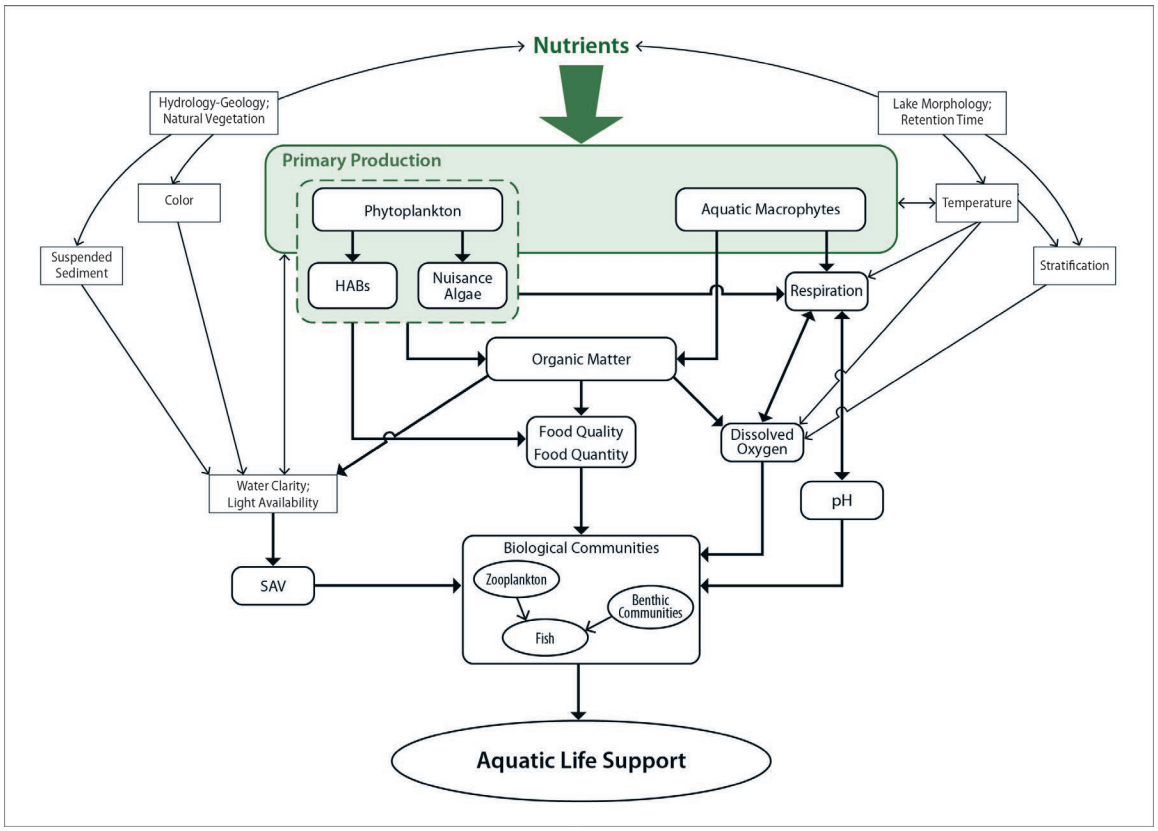

Figure 1. Conceptual model linking increased nutrients to aquatic life use (*Source*: US EPA 2010a).

2.2.1 Aquatic Life Use

Nutrient pollution and eutrophication can affect the health of the lake biological community via many pathways (see Figure 1). As discussed earlier, increased nutrients typically stimulate primary productivity and increase the amount of organic matter in a lake. Decomposition of the organic matter depletes the DO in the water, reducing the suitability of deeper waters as habitat for fish and invertebrates (Cornett 1989). Increased production and respiration also can increase the range of acidity throughout the day-night cycle in some lakes (Schindler et al. 1985), reducing the suitability of shallow waters as habitat for certain species. Increased algal biomass also reduces water clarity, and the reduction in light availability limits the depths at which submerged aquatic vegetation can persist (Phillips et al. 2016). Reduced water clarity can also shift fish assemblage composition away from species that depend on sight for foraging (De Robertis et al. 2003). Further, high nutrient concentrations favor the growth of cyanobacteria, which are less palatable to grazing species than other phytoplankton, altering the food web of the lake (Haney 1987).

EPA selected two assessment endpoints to characterize the health of aquatic life in lakes: (1) zooplankton biomass, which is applicable to all lakes, and (2) the survival and growth of cool- and cold-water fish in seasonally stratified lakes. For the second endpoint, EPA selected depth-averaged DO concentration as the risk metric. In seasonally stratified lakes with cool-water fish, criteria based on zooplankton biomass and DO can be compared, and the more stringent criterion is applied to ensure that aquatic life is protected. Collectively, the two assessment endpoints provide a broad assessment of the health of the lake biological community. Data were also available for each endpoint, and each endpoint quantified well-studied effects of nutrient pollution.

2.2.1.1 Zooplankton biomass

The rate of change of zooplankton biomass compared to the rate of change of phytoplankton biomass quantifies changes in the shape of biomass pyramids in lakes (Elton 1927). Biomass pyramids provide a graphical depiction of the amount of biomass at different trophic levels, and typically, the biomass of primary producers (at the bottom of the pyramid) exceeds the biomass of herbivores and carnivores at successively higher levels of the pyramid. In lakes, the ratio of herbivore biomass (i.e., zooplankton) to primary producer biomass (i.e., phytoplankton) (Z:P) has been observed to decrease along eutrophication gradients (Leibold et al. 1997). Reasons for the decreasing trend in Z:P have been the subject of some debate, much of which centers on the relative importance of top-down versus bottom-up food web effects. For zooplankton, top-down forces consist mainly of the effects of planktivore fish consuming zooplankton biomass (Jeppesen et al. 2003) and bottom-up forces include changes in the quantity and quality of the phytoplankton assemblage on which zooplankton feed (Filstrup et al. 2014a). With excess nutrients, one particularly important bottom-up mechanism is the decrease in the edibility of the phytoplankton assemblage associated with the increased dominance of cyanobacteria with increasing levels of eutrophication. Laboratory studies demonstrate that the lack of highly unsaturated fatty acids in cyanobacteria negatively affects the growth rates of a common zooplankton species (Daphnia) (Demott and Müller-Navarra 1997, Persson et al. 2007). Field observations (Müller-Navarra et al. 2000) and microcosm experiments (Park et al. 2003) have added further support for this finding. Many cyanobacteria also present physical challenges to grazers, collecting in colonies or filaments that are too large to be consumed (Bednarska and Dawidowicz 2007), or surrounding themselves with gelatinous sheaths (Vanni 1987). Altered

elemental stoichiometry and, hence, nutritional quality of phytoplankton under different levels of eutrophication may also influence zooplankton biomass (Hessen 2008).

The *rate* of change of zooplankton biomass with respect to increasing phytoplankton biomass (ΔZ/ΔP) provides an informative measure of the effects of eutrophication on food web function for the purposes of informing the derivation of numeric nutrient criteria (Yuan and Pollard 2018). This rate of change can be thought of as the slope of the relationship between Z and P. In most lake food webs, any increase in the basal resources (i.e., phytoplankton biomass) would be expected to be associated with a corresponding increase in the biomass of consumers of those resources (i.e., zooplankton biomass), and the slope between Z and P would be positive. In eutrophic lakes, however, increases in phytoplankton biomass often are not associated with an increase in zooplankton biomass, and the slope (ΔZ/ΔP) approaches zero (Leibold et al. 1997, Hessen et al. 2006, Heathcote et al. 2016). Based on this observation, EPA used the rate of change in zooplankton biomass relative to changes in phytoplankton biomass (ΔZ/ΔP) as a measure of the effect of excess nutrients on lake food webs.

2.2.1.2 Dissolved oxygen

Excess nutrients typically increase primary productivity, which increases the amount of organic matter in a lake. Then, DO is consumed as the organic matter is decomposed, leading to hypoxic and anoxic conditions (see Figure 1). Low concentrations of DO limit the extent to which habitat is available to fish and zooplankton (Colby et al. 1972, Tessier and Welser 1991, Vanderploeg et al. 2009), and oxygen availability is a key determinant of the quality and quantity of habitat available to aquatic biota in many lakes (Evans et al. 1996). Although hypoxia occurs naturally in a small number of systems (Diaz 2001), anthropogenic nutrient loads have greatly increased the occurrence of hypoxia worldwide (Jenny et al. 2016). Deoxygenation of lake water typically begins near the lake bottom and proceeds to shallower depths over the summer, especially in stratified, relatively deep lakes, where the replenishment of DO from surface mixing is restricted (Cornett 1989, Wetzel 2001). Therefore, an increasing proportion of the deeper waters of a lake can become uninhabitable for certain organisms over the course of the summer (Molot et al. 1992). Exclusion of deeper waters as viable habitat, in particular, can disproportionately affect particular species of adult and juvenile fish (Lienesch et al. 2005).

Another strong determinant of the available habitat for fish and zooplankton is water temperature. Summer brings a longer photoperiod and more intense solar insolation, which

increases water temperatures near the surface of many lakes to levels harmful to certain species (Ferguson 1958, Eaton and Scheller 1996). The viable habitat for cool- and cold-water species, in particular, can be restricted by surface warming (Jacobson et al. 2010, Arend et al. 2011). In contrast to deoxygenation, warming starts at the surface of the lake and proceeds to deeper depths over the course of the summer. Therefore, certain species of fish are "squeezed" between increasing temperatures at shallow depths and decreasing DO at deeper depths (Coutant 1985, Stefan et al. 1996, Lee and Bergersen 1996, Plumb and Blanchfield 2009), requiring them to choose between suboptimal temperatures or oxygen (Arend et al. 2011). Under those conditions, the metalimnion and the upper edge of the hypolimnion can provide an important refuge, and even a thin layer of cool water with sufficient DO can provide an important habitat for supporting fish health through the warmest summer days. Because they often can tolerate lower DO concentrations than fish, zooplankton can retreat to deeper depths of the hypolimnion to escape fish predation, but are also limited ultimately by low DO concentrations (Tessier and Welser 1991, Stemberger 1995).

Based on these considerations, the mean concentration of DO below the thermocline was identified by EPA as an appropriate metric for assessing risks to cool- and cold-water fish in seasonally stratified lakes. In those lakes during the summer, the availability of cool-water habitat is constrained by deep water DO concentrations, and so, this risk metric links increased nutrient concentrations to deleterious effects affecting the survival of fish and zooplankton in deep lakes.

2.2.2 Recreational Use

EPA selected the concentration of cyanotoxins as the risk metric linking increased nutrients to the suitability of lake water for primary and secondary contact recreation. Increased nutrient concentrations and an attendant increase in cyanobacterial abundance can increase concentrations of cyanotoxins (Figure 2), which cause adverse effects on the health of people exposed to the water (US EPA 2019). One of the most commonly occurring types of cyanotoxins in freshwaters is microcystins (based on available data). To protect recreational uses of lakes, EPA identified microcystin concentration as the best risk metric because of the availability of National Lakes Assessment (NLA) data (US EPA 2010b) and because microcystin thresholds for recreational exposures have recently been published (US EPA 2019).

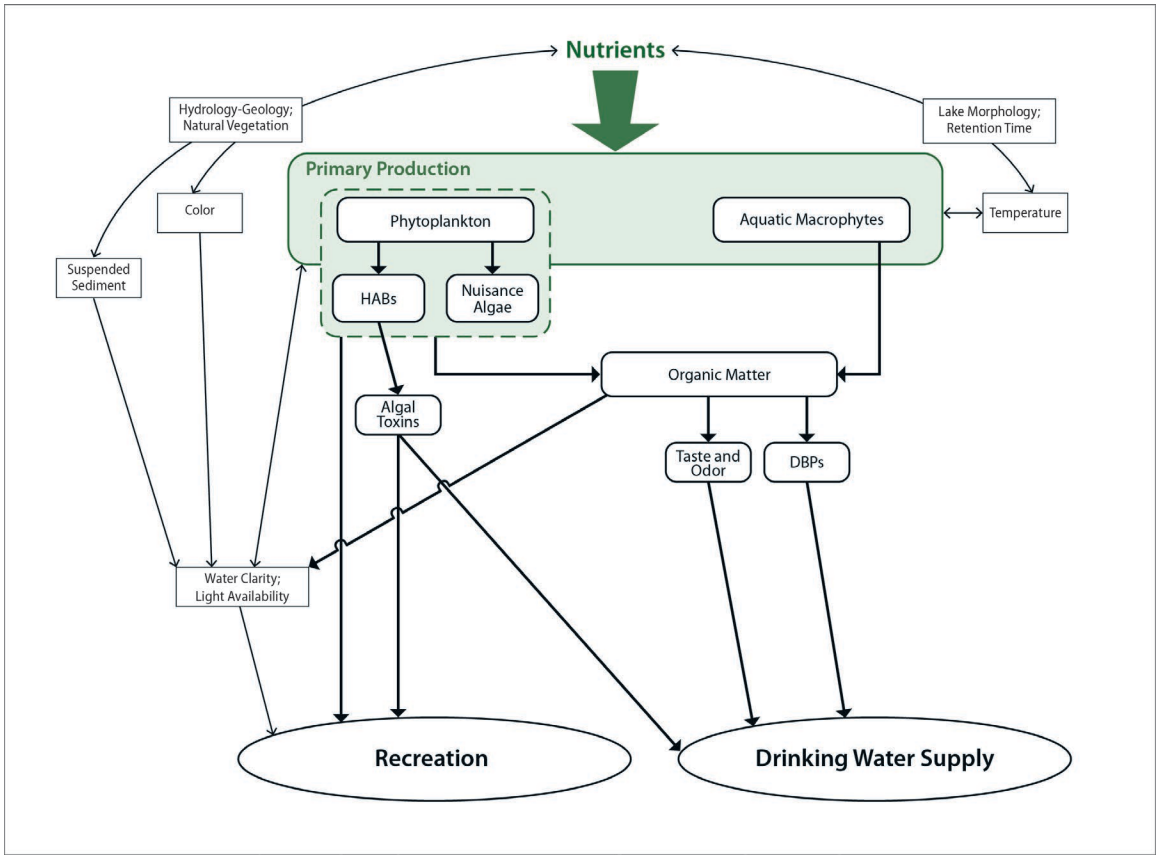

Figure 2. Conceptual model linking increased nutrient concentrations to public health endpoints.

2.2.3 Drinking Water Source

Increased nutrient concentrations and an attendant increase in cyanobacteria can increase concentrations of cyanotoxins, which are toxic when consumed at certain concentrations and quantities (see Figure 2) (Chorus 2001, Stewart et al. 2008, US EPA 2015b). As was done for recreational use, EPA selected microcystin in lake source water as the risk metric for the drinking water use.

2.3 Risk Hypotheses

EPA specified risk hypotheses for each of the selected assessment endpoints. Based on a survey of available literature, EPA concluded that increased concentrations of N and P increase the risk to both ecological and human health (Figure 3). For aquatic life, the risk hypotheses consist of the pathway in which increased nutrient concentrations increase phytoplankton biovolume (measured as chlorophyll *a* [Chl *a*]). Then, as phytoplankton biovolume and associated biomass increase, the relationship between zooplankton biomass and phytoplankton biomass ($\Delta Z/\Delta P$)

changes so that increases in phytoplankton biomass are no longer associated with increases in zooplankton biomass, and increases in primary production at the base of the lake food web are not transferred to higher trophic levels. For the case of deep water DO concentrations, increased phytoplankton biomass increases organic matter in the lake, which, when decomposed, consumes DO (Walker 1979). The decreased concentrations of DO then affect lake aquatic life. The risk hypotheses for both recreation and drinking water source designated uses state that increased nutrient concentrations increase the biovolume of cyanobacteria and concentrations of microcystin.

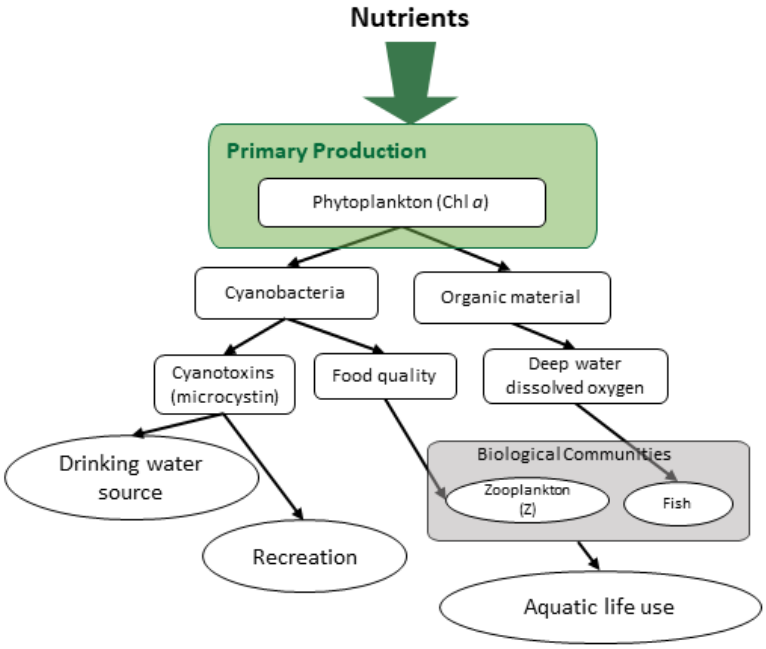

Figure 3. Simplified conceptual model showing pathways selected for analysis.

2.4 Analysis Plan

An analysis plan outlines the scope, approaches, and methods to be used in the risk assessment. Here, the analysis plan consists of acquiring appropriate data and estimating relationships between phytoplankton biovolume and each of the risk metrics as well as between N, P, and phytoplankton biovolume. The critical measurement in all these relationships is Chl *a*, which is closely associated with phytoplankton biovolume. Stressor-response analysis was applied to available data to estimate relationships between nutrient concentrations and different risk metrics. Because Chl *a* concentration is the critical parameter for all risk metrics, EPA developed

different stressor-response models associating Chl *a* concentration with each of the risk metrics (i.e., zooplankton biomass (ΔZ/ΔP), deep water DO concentration, and microcystin). The models then yielded candidate criteria for Chl *a* corresponding to each of the risk metrics (and their associated endpoints). A candidate Chl *a* criterion is defined as a protective concentration associated with a particular risk metric and/or with a particular designated use. The final criterion for a lake is then derived by comparing candidate criteria and selecting the criterion that protects the most sensitive use. N and P are estimated in field measurements as TN and TP, and so, EPA developed models relating TN and TP concentrations to Chl *a* concentrations that can translate each of the different Chl *a* criteria into recommended TN and TP criteria.

Because different risk metrics have been identified for each of the three designated uses, these risk metrics lead to the derivation of different recommended numeric nutrient criteria. In general, a state's water quality criteria for any single lake would need to protect the most sensitive use (i.e., the state should select the most stringent numeric nutrient criteria across all relevant uses and endpoints) (40 CFR 131.11(a)(1)).

3 Analysis

Because stressor-response analyses for each of the risk metrics differed substantially from one another, most of this section is organized by models for the different risk metrics—zooplankton biomass, deep water hypoxia, and microcystin—followed by models relating TN, TP, and Chl *a*. Because the same data were used to fit each of these models, all the data used in the analyses are discussed first.

3.1 Data

EPA analyzed data collected in the NLA in the summers (May–September) of 2007 and 2012 to support the derivation of recommended numeric nutrient criteria. The NLA data were collected from a random sample of lakes from the continental U.S. In 2007, lakes with surface areas larger than 4 hectares and, in 2012, lakes larger than 1 hectare were selected from the contiguous U.S. using a stratified random sampling design (US EPA 2012c). The final data set was supplemented by a small number of hand-picked lakes identified as being less disturbed by human activities (US EPA 2010b). The additional lakes were included to increase the number of least-disturbed lakes for which data were available, and by helping ensure the full range of conditions was

sampled, data from the additional lakes were expected to improve the accuracy of the estimated stressor-response relationships. The overall sampling design of the NLA was synoptic, but 10% of sampled lakes were randomly selected and resampled on a different day after the initial visit. The timing of the second visit varied among lakes, but on average, the second sample was collected approximately 46 days after the first. Approximately 20% of the lakes were sampled in both 2007 and 2012. The sampling day of the year was recorded for each visit and used in subsequent analyses to account for temporal changes in deep water DO concentration. Overall, data from approximately 1,800 different lakes are included in the data set, but the specific number of samples used to estimate each stressor-response relationship varies slightly based on data available at each lake. The specific number of samples is provided in the subsequent discussion of each model. Quality assurance project plans for the NLA are available in separate publications (US EPA 2009, 2012b).

During each visit to a selected lake, an extensive suite of abiotic and biological variables was measured. Only brief details on sampling protocols are provided here regarding the parameters used to derive these criterion models; more extensive descriptions of sampling methodologies are available in the NLA documentation (US EPA 2007, 2011). A sampling location was established in open water at the deepest point of each lake (up to a maximum depth of 50 meters [m]) or in the mid-point of reservoirs. In 2012, an additional sampling location for collection of microcystin, algae, and Chl *a* data was established in the littoral zone approximately 10 m away from a randomly selected point on the shoreline.

At the open water site, a vertical, depth-integrated methodology was used to collect a water sample from the photic zone of the lake (to a maximum depth of 2 m). Multiple sample draws were combined in a rinsed, 4-liter (L) cubitainer. When full, the cubitainer was gently inverted to mix the water, and an aliquot was taken as the water chemistry sample. That subsample was placed on ice and shipped overnight to the Willamette Research Station in Corvallis, Oregon. A second aliquot was taken to use in characterizing the phytoplankton community and was preserved with a small amount of Lugol's solution. A Secchi depth measurement was also collected at this site. Two zooplankton samples were collected with vertical tows for a cumulative tow length of 5 m using fine- (50-micrometer- [-µm-]) and coarse- (150-µm-) mesh Wisconsin nets. In lakes at least 7 m deep, one 5-m deep tow was collected with each mesh. In

shallower lakes, vertical tows over shorter depths were combined to reach the cumulative tow length of 5 m.

At the littoral zone site, two grab water samples were collected 0.3 m below the surface where the lake was at least 1 m deep using a 2-L brown bottle. The first sample was split into two subsamples: one subsample for quantifying algal toxin concentration and the second subsample preserved with a small amount of Lugol's solution and used to characterize the phytoplankton community. The second grab sample collected with the 2-L bottle was used to quantify Chl *a* concentration.

3.1.1 Biological Data

Phytoplankton biovolume from the field samples was measured in the laboratory. Samples collected from both open water and littoral zone locations were examined by taxonomists, who identified at least 400 natural algal units to species under 1,000× magnification. Observations were aggregated and abundance was calculated as cells per milliliter. In each sample, the dimensions of the taxa that accounted for the largest proportion of the observed assemblage were measured and used to estimate biovolume. Biovolumes of the most abundant taxa were based on the average of measurements from at least 10 individuals, while biovolumes of the less abundant taxa were based on somewhat fewer measurements. The biovolume was reported as cubic micrometers per milliliter ($\mu m^3/mL$) (US EPA 2012a), which was converted to cubic millimeters per liter (mm^3/L). Approximately 5% of the phytoplankton samples were randomly selected and reidentified and measured by a second taxonomy laboratory. These reidentified samples provided a basis for estimating laboratory measurement error. Biovolume measurements were converted to biomass using a density of 1 gram per milliliter (g/mL) (Holmes et al. 1969).

Zooplankton samples from the coarse- and fine-mesh net tows were processed separately. In each sample, zooplankton specimens were examined and counted under 100–1,000× magnification in discrete subsamples until at least 400 individuals were identified. In the coarse-mesh net samples, all taxa were identified and enumerated. In the fine-mesh net, only "small" taxa were identified and enumerated (Cladocera less than 0.2 millimeters [mm] long, copepods less than 0.6 mm long, rotifers, and nauplii). Zooplankton abundance was estimated based on the volume of sampled lake water used to identify the targeted count of 400 individuals. Measurements of at least 20 individuals were collected for dominant taxa (i.e., taxa

encountered at least 40 times in the subsample); at least 10 individuals were measured for taxa encountered from 20 to 40 times; and at least 5 individuals were measured for rare taxa (encountered less than 20 times in the subsample). Zooplankton biomass estimates were based on existing length and width relationships (Dumont et al. 1975, McCauley 1984, Lawrence et al. 1987). Estimates from the coarse- and fine-mesh samples were added to yield a single zooplankton sample per lake visit.

3.1.2 Chemical Data

For both 2007 and 2012 data, TN, nitrate-nitrite (NO_x), ammonia, and TP concentrations; true color, dissolved organic carbon (DOC) concentration, turbidity, and acid-neutralizing capacity (ANC) were measured in the laboratory from the open water sample at prespecified levels of precision and accuracy (US EPA 2012a). Typical laboratory methods included persulfate digestion with colorimetric analysis for TN and TP, nephelometry for turbidity, comparison to a calibrated color disk for true color, and automated acidimetric titration for ANC. To measure Chl *a* concentration, 250 mL of lake water was pumped through a glass fiber filter in the field and quantified in the laboratory to prespecified levels of precision and accuracy. Examples of lower reporting limits include 20 µg/L for TN, 4 µg/L for TP, and 0.5 µg/L for Chl *a*.

Microcystin sample processing began with three sequential freeze/ thaw cycles to lyse cyanobacteria (Loftin et al. 2008). Processed samples were filtered using 0.45 µm polyvinylidene difluoride membrane syringe filters and stored frozen until analysis. The concentration of microcystin in the filtered water sample was measured with an enzyme-linked immunosorbent assay (ELISA) using an Abraxis kit for Microcystin-ADDA, which employs polyclonal antibodies that are unique to microcystins and other similar compounds. The binding mechanism of the Microcystin-ADDA assay is specific to the microcystins, nodularins, and their congeners; therefore, results from that assay could include contributions from any compound within the ADDA functional group (Fischer et al. 2001). The minimum reporting level for the assay was 0.1 µg/L as microcystin-LR.

3.1.3 Dissolved Oxygen and Temperature Profiles

At the deepest point of each lake (or in the midpoint of reservoirs), a multiparameter water quality meter was used to measure profiles of DO concentrations, temperature, and pH at a minimum of 1-m depth intervals (see Section 3.2.2 for an examples of depth profiles). Profiles in

lakes less than 3 m deep were sampled at 0.5-m depth intervals. Water temperatures were converted to estimates of water density (Jones and Harris 1992), and density gradient was estimated between all available depths below 0.5 m as the difference in density between two successive measurements divided by the difference in the depths of the two measurements. Temperature gradients were computed with the same approach. Samples collected in the uppermost 0.5 m were excluded to limit the effects of surface warming on the gradient calculations.

3.1.4 Mapped Data

Lake physical characteristics, including lake surface area, geographic location (latitude and longitude), elevation, lake catchment area, and lake perimeter, were estimated from mapped data. From these characteristics, the following composite variables were calculated: (1) the drainage ratio, which is defined as the ratio of catchment area to lake surface area and characterizes the degree to which the lake catchment influences the lake; (2) the shoreline development, which is defined as the ratio between the perimeter of the lake and the perimeter of a circle with the same area as the lake and characterizes the geometric complexity of the lake shore; and (3) the lake geometry ratio, which is defined as $area^{0.25}$/depth, or the ratio between fetch and lake maximum depth, and has been shown to differentiate lakes that stratify seasonally (low values of the geometry ratio) from lakes that are polymictic (Gorham and Boyce 1989, Stefan et al. 1996). Variables quantifying the mean annual precipitation and mean annual air temperature at the lake location were extracted from 30-year averaged climatic data (Daly et al. 2008).

3.2 Stressor-Response Models

Stressor-response models estimate relationships between environmental stressors (e.g., increased nutrient concentrations) and responses, or risk metrics. In this section, stressor-response models for zooplankton biomass, deep water hypoxia, and microcystin concentration are described. The stressor in these models is phytoplankton biovolume, quantified as Chl *a*. Models estimating relationships between TN, TP, and Chl *a* are also described.

3.2.1 Zooplankton Biomass

Zooplankton occupy a key link in the lake food web, and the relationship between phytoplankton biovolume and zooplankton biomass provides insights into changes in the food web as lake productivity increases.

3.2.1.1 Statistical analysis

EPA specified a Bayesian network model to estimate the relationship between summer mean phytoplankton and zooplankton biomasses (Figure 4). A Bayesian network provides a unified framework for modeling the cascading relationships between different measurements and propagates estimation errors and model uncertainty correctly throughout the model (Qian and Miltner 2015; Yuan and Pollard 2018).

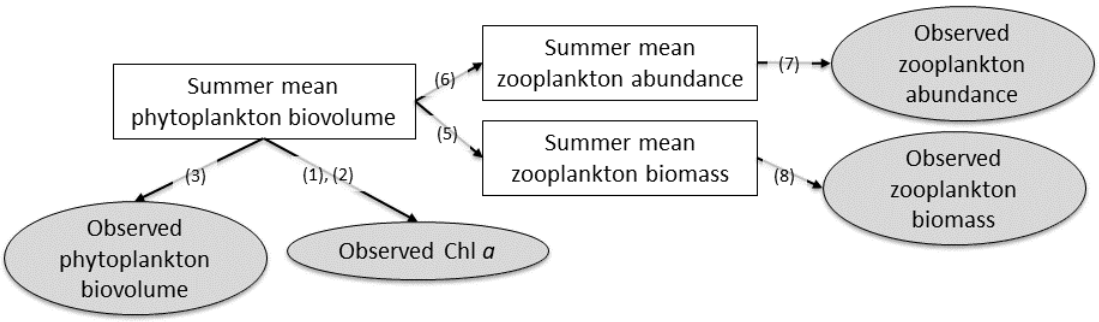

Figure 4. Schematic of network of relationships for modeling zooplankton biomass. *Gray-filled ovals*: available observations*; other nodes*: modeled parameters*; numbers in parentheses* refer to equation numbers in the text.

The first set of relationships in the network estimated seasonal mean phytoplankton biovolume based on measurements of Chl *a* concentration and of phytoplankton biovolume. The two measurements provided independent estimates of phytoplankton biovolume, each with different sources of error. Chl *a* is measured precisely from field samples, but the Chl *a* content of phytoplankton can vary depending on environmental conditions and species composition (Kasprzak et al. 2008), so that a measured Chl *a* concentration in one sample might indicate a slightly different phytoplankton biovolume than the same Chl *a* measured in another sample. Hence, Chl *a* concentration is modeled as being directly proportional to the seasonal mean phytoplankton biovolume in lake *j* (P_j), but the constant of proportionality, *b*, (i.e., the Chl *a*

content of phytoplankton in a sample) is allowed to vary among samples. The log-transformed version of this model equation is as follows:

$$\log(Chl_i) = \log\left(P_{j[i]}\right) + \log(b_i) \quad (1)$$

$$\log(b_i) \sim Normal(\mu_b, \sigma_b) \quad (2)$$

where the value of b_i for each sample, *i*, is drawn from a single log-normal distribution characterized by a mean, μ_b, and a standard deviation, σ_b. The mean value, μ_b, accounts for differences in the measurement units of Chl *a* and phytoplankton biovolume; however, in the model, both Chl *a* and phytoplankton biovolume measurements are standardized by subtracting their observed mean values and dividing by their standard deviation, so μ_b is zero. The multilevel expression of the model equation allows the mean Chl *a* content of phytoplankton cells estimated for each sample to vary, but imposes the constraint that estimates of phytoplankton Chl *a* content for each sample must be drawn from a common log-normal distribution (Gelman and Hill 2007). Measurements collected at the same lake on different days and collected on the same day in the littoral zone and in the middle of the lake were used to estimate seasonal mean phytoplankton biovolume.

Direct measurements of phytoplankton biovolume provide an unbiased estimate of true phytoplankton biovolume. These direct measurements, however, are obtained by summing contributions from measurements taken from many different individual phytoplankton, each of which includes measurement error. Hence, the summed estimate of total biovolume includes a substantial amount of measurement error. That measurement error was explicitly modeled, and a second estimate of the seasonal mean phytoplankton biovolume was expressed as follows:

$$\log\left(P_{obs,i}\right) \sim Normal\left(\log\left(P_{j[i]}\right), s_1\right) \quad (3)$$

where $P_{obs,i}$ is the observed phytoplankton biovolume in sample *i*. Final model estimates of $P_{j[i]}$ were consistent with both Chl *a* and observed phytoplankton biovolume, and by combining the two measurements, the accuracy of the final estimate was maximized.

Zooplankton abundance (A) and biomass (Z) were modeled as increasing functions of seasonal mean phytoplankton biovolume (or biomass, using the conversion factor of 1 g/mL). Previous studies in oligotrophic lakes found that zooplankton biomass increased as a constant proportion of phytoplankton biomass (Rognerud and Kjellberg 1984, del Giorgio and Gasol 1995). That is,

after log-transforming, the relationship between P and Z should approach the following at low concentrations of P:

$$\log(Z) = \log(k) + \log(P) \quad (4)$$

where the slope of the relationship between log(Z) and log(P) approaches 1. In contrast, in eutrophic lakes, minimal changes in Z were observed with changes in P, and the slope between log(Z) and log(P) approached zero (Yuan and Pollard 2018). Those patterns guided the selection of the following functional form for modeling the relationship between log(Z) and log(P):

$$E[\log(Z_j)] = f_1 + f_2 \log(P_j) - f_3 q \log\left[1 + \exp\left(-\frac{\log(P_j) - c_p}{q}\right)\right] \quad (5)$$

where, in general, *E[.]* indicates the expected value of the variable enclosed in the square brackets. The coefficients f_1, f_2, f_3, c_p, and q were estimated from observations of Z_j and the estimated seasonal mean phytoplankton concentration, P_j, estimated from measurements of phytoplankton biovolume and Chl *a*. The slope of this function approaches f_2 at large values of P and approaches a slope of $f_2 + f_3$ at low values of P. A prior distribution for $f_2 + f_3$ was specified as a normal distribution centered at 1 with a standard deviation of 0.2, expressing the prediction (stated above) that, at low levels of phytoplankton (oligotrophic lakes), zooplankton biomass should increase as a constant proportion of phytoplankton biomass.

A similar model was specified for zooplankton abundance (A) as follows:

$$E[\log(A_j)] = a_1 + a_2 \log(P_j) + a_3 \log\left[1 + \exp\left(-\frac{\log(P_j) - c_p}{r}\right)\right] \quad (6)$$

where the parameters, a_1, a_2, a_3, and r were estimated from the data, and the third term on the right side of the equation again introduces curvature in the fitted relationship. The change point for zooplankton abundance, c_p, was estimated as being the same as for zooplankton biomass because of the strong influence of abundance on total biomass. In the case of zooplankton abundance, no *a priori* assumptions about the slope of the relationship at high or low levels of phytoplankton guided the choice of parameter values.

Observed values of zooplankton abundance and biomass were then related to the estimated expected values as follows:

$$\log(A_{obs,i}) \sim Normal(\mathrm{E}[\log(A_{j[i]})], s_2) \quad (7)$$

$$\log(Z_{obs,i}) \sim Normal(\mathrm{E}[\log(Z_{j[i]})], s_3) \quad (8)$$

Similar to the model equations for phytoplankton, variability in the observations of zooplankton abundance and biomass relative to estimated mean values were modeled as log-normal distributions with standard deviations of s_2 and s_3. These error terms included contributions from temporal, sampling, and measurement error.

Because the strength of the interaction of the zooplankton assemblage with benthic resources was expected to differ between shallow and deep lakes (Benndorf et al. 2002, Scheffer and van Nes 2007) and exploratory data analysis indicated that lake depth was an important covariate (Yuan and Pollard 2018), different parameter values for a_1, a_2, a_3, f_1, f_2, f_3, and c_p were estimated for each of three classes of lakes defined by depth. The curvature parameters q and r were fixed at 1. The number of lake classes was specified to balance between accounting for differences in lake depth and maintaining enough samples within each class to estimate relationships. Depth thresholds defining each class were selected to ensure that a similar number of samples was assigned to each class, yielding the following thresholds: less than 3.8 m, 3.8–8.0 m, and more than 8.0 m.

All model equations were fit simultaneously to data collected at each lake, including revisits on different days, and littoral and mid-lake samples for phytoplankton. Weakly informative priors were specified for all model parameters except for $f_2 + f_3$ (Gelman 2006). Weakly informative prior distributions constrain parameter estimates away from extreme values, while allowing the data to determine the estimate for each parameter. All other statistical calculations were performed with R, an open-source statistical modeling software (R Core Team 2017). Hierarchical Bayesian models were fit using the rstan library, which implements the No-U-Turn sampler, a variant of a Hamiltonian Monte Carlo sampling approach (Duane et al. 1987, Stan Development Team 2016).

3.2.1.2 Results

Data collected at a total of 1,096 lakes were available for analysis, with approximately 330 lakes assigned to each depth class. Estimated mean phytoplankton biovolume within each sample was much more strongly associated with Chl *a* concentration than with measured phytoplankton biovolume, because of the high variability associated with measured phytoplankton biovolume (Figure 5).

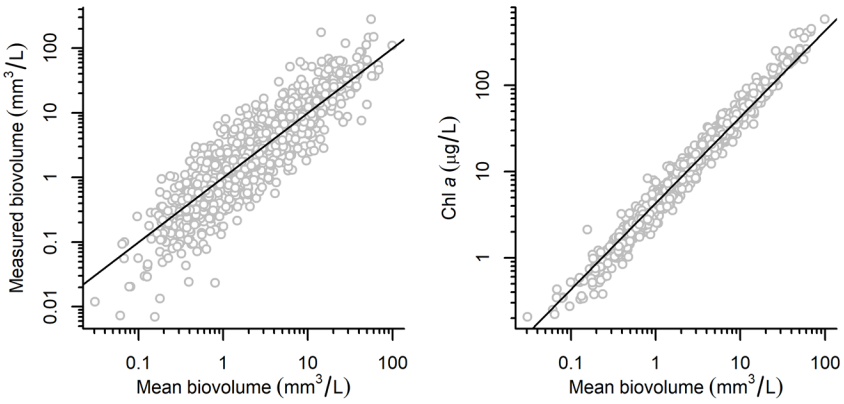

Figure 5. Relationships between measured biovolume, Chl *a*, and estimated seasonal mean phytoplankton biovolume. Solid lines: 1:1 relationship (left panel), proportional relationship (right panel).

Estimated relationships between phytoplankton biomass (as quantified by Chl *a*) and zooplankton abundance and biomass matched trends observed in the data (see Figure 6 for an example for lakes deeper than 8 m in left and middle panels, respectively). The relationship between zooplankton biomass and phytoplankton biomass also was consistent with the initial assumption that, in oligotrophic lakes with low levels of phytoplankton biomass, the slope approached 1, and in eutrophic lakes with high levels of phytoplankton biomass, the slope approached zero (right panel, Figure 6).

The models show the gradual change in the shape of the biomass pyramid along the eutrophication gradient. In oligotrophic lakes, the slope of the relationship between zooplankton and phytoplankton biomass is near 1, indicating that small increases in phytoplankton biomass are reflected in a proportional increase in zooplankton biomass. As Chl *a* increases, however, the slope decreases, and the increase in zooplankton biomass per unit of increase in phytoplankton biomass [$\log(\Delta Z)/\log(\Delta P)$] approaches zero. In eutrophic lakes, increases in phytoplankton biomass do not result in comparable changes in zooplankton biomass. These changes along the eutrophication gradient are consistent with other similar studies, as reviewed in Yuan and Pollard (2018).

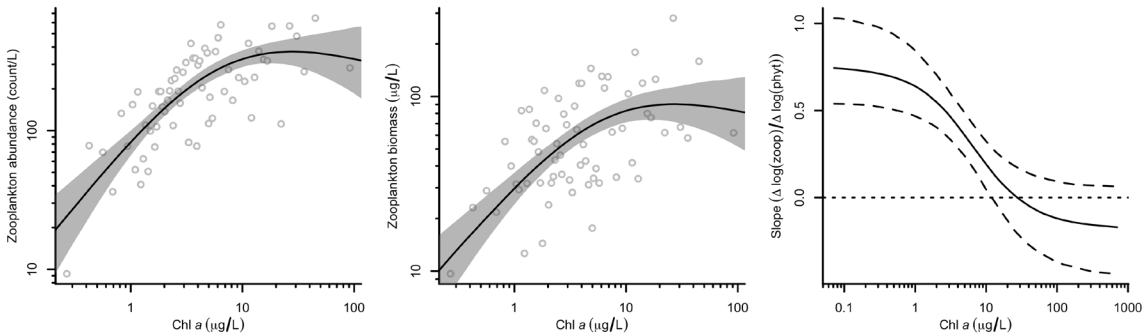

Figure 6. Estimated relationships between zooplankton and Chl *a* for lakes > 8 m deep. *Left panel*: Chl *a* vs. zooplankton abundance; *middle panel*: Chl *a* vs. zooplankton biomass; *right panel*: Chl *a* vs. slope of the relationship between zooplankton biomass and Chl *a. Solid lines*: mean relationships; *shaded areas* (*left and middle panels*): 90% credible intervals (bounded by the 5th and 95th percentiles of the distribution of possible mean relationships; *dashed lines* (*right panel)*: 90% credible interval; *open circles (left and middle panels)*: average of five samples nearest the indicated Chl *a* concentration; *dotted horizontal line* (*right panel*): one example value of threshold for deriving a Chl *a* criterion.

3.2.1.3 Chl a criterion derivation

Calculating candidate criteria for Chl *a* based on this response requires the specification of two parameters—the value of the slope between log(Z) and log(P) and the certainty level, as quantified by the credible interval (i.e., the Bayesian analog to a confidence interval).

Considerations: Slope between log(Z) and log(P). The threshold slope of zero between log(Z) and log(P) is the limit beyond which changes in zooplankton biomass are not associated with changes in phytoplankton biomass. This threshold identifies the point at which a disconnect between phytoplankton and zooplankton production begins and increasing primary productivity in the lake escapes zooplankton grazer control, a condition which can exacerbate blooms. EPA therefore recommends a threshold of zero as the minimum value for this parameter. Higher threshold slopes may be selected for certain types of lakes in which a higher proportion of phytoplankton is expected to be consumed by zooplankton (e.g., oligotrophic), but quantifying the appropriate value for this slope requires the collection of additional data from these lakes. Graphically, this threshold defines the horizontal line on which the Chl *a* criterion will be based (see Figure 6).

Considerations: Certainty level. The certainty level, as quantified by the credible interval, expresses the statistical uncertainty about the position of the mean relationship and is comparable to a confidence interval used in frequentist statistics. The percentile value selected as the certainty level (e.g., the 90% certainty level) specifies the probability that the mean

relationship is located within the estimated bounds of the corresponding credible interval (e.g., there is a 90% probability that the actual mean relationship is located within the bounds associated with the 90% credible interval). In practice, the bounds of the credible interval are calculated from percentiles of the posterior distribution of the mean relationship. For example, at any Chl *a* concentration, the criterion model provides a distribution of possible values of the slope between zooplankton and phytoplankton biomasses. The credible interval is centered at the median value of this distribution of slopes, and the bounds of the 90% credible interval are calculated as the 5th and 95th percentiles of this distribution.

Basing the criterion value on the lower bound of the selected credible interval provides additional assurance that the calculated criterion is protective, given the data and model uncertainty. That is, more protective criteria are based on lower percentiles of the distribution of possible mean relationships (i.e., lower bounds of the credible interval). For example, if one selects a certainty level of 90%, the corresponding bounds for the 90% credible interval are computed as the 5th and 95th percentiles of the distribution of estimated mean relationships. Therefore, basing a criterion on the lower bound of the 90% credible interval implies there is a 5% chance that the actual slope between log(Z) and log(P) is less than the selected threshold. That is, there is a 5% chance that the derived criterion value is greater than the concentration needed to achieve the desired condition, and therefore, a 5% chance that the criterion is under-protective. More certainty on the criterion value is achieved by selecting greater certainty levels. For example, there is a 1% chance that a criterion based on the 98% certainty level would be under-protective. In statistical hypothesis testing, convention suggests that *p*-values of 1% or 5% are statistically significant results, which can also inform the selection of the certainty level.

Selection of the certainty level as the basis for the criteria is a management decision, and a range of certainty levels (and associated credible intervals) from 50% to 99% is provided in the associated interactive tool (see below). The ecological effects of reduced grazer control of phytoplankton biomass associated with a slope threshold value of zero can be substantial and difficult to reverse; and therefore, conservative certainty levels (i.e., 90% - 99%) are recommended for this response.

Chl *a* criterion derivation: Illustrative criteria for Chl *a* for different management decisions are shown in Table 2. The interactive tool, which uses posterior simulation with the estimated parameter distributions, computes candidate criteria for different combinations of the slope

threshold and the certainty level (https://nsteps.epa.gov/apps/chl-zooplankton). With this tool, a user can specify the value of the slope between log(Z) and log(P), lake depth, and the certainty level, and the associated criteria and stressor-response relationship are updated to reflect those selections. The tool provides transparent information regarding the effects of different levels of certainty and can provide a useful means of engaging with stakeholders regarding the risk management decisions underlying criterion development.

Table 2. Illustrative Chl *a* criteria (µg/L) for different certainty levels and a slope threshold value of 0 for Δ(log Z)/Δ(log P). Values shown for each lake depth class.

	Depth class		
Certainty level	**< 3.8 m**	**3.2 – 8 m**	**> 8 m**
90%	51	21	13
99%	34	15	9

3.2.2 Deep Water Hypoxia

EPA specified a model for deep water DO that represents the temporal decrease in DO during summer stratification, while accounting for differences among lakes in eutrophication status, depth, and DOC concentrations (Yuan and Jones 2020a).

3.2.2.1 Data

EPA first restricted analysis to data collected from seasonally stratified lakes because hypoxic and anoxic conditions occur more consistently during stratified conditions. Lakes were identified that were likely to be seasonally stratified by computing the lake geometry ratio. This metric approximates the relative effects of lake fetch and depth on stability of stratification, and lakes with a geometry ratio less than 3 $m^{-0.5}$ exhibit seasonal stratification (Gorham and Boyce 1989). Therefore, EPA restricted NLA data to lakes with geometry ratios less than that threshold. Lakes likely to be dimictic (i.e., mixing fully in the spring and in the fall and ice-covered in the winter) were also identified based on latitude and elevation. This classification approach adjusts the lake latitude by elevation, and then identifies lakes with *adjusted* latitudes greater than 40˚ N as dimictic (Figure 7) (Lewis 1983). Restriction to dimictic lakes allowed EPA to use a simple relationship based on annual mean temperature in the model to more accurately predict the first day of stratification, and thus, more accurately estimate model parameters (see below). The location of dimictic lakes also roughly corresponded with lakes that were likely to harbor

cool- and cold-water fish. Finally, data were restricted to samples in which temperature profiles exhibited evidence of stratification (defined as a temperature gradient of at least 1 degree Celsius per meter [°C/m]).



Figure 7. Locations of NLA lakes used to fit the DO_m model. These lakes were designated as dimictic and were stratified at the time of sampling.

Mean deep water DO concentrations (DO_m) in the selected NLA lakes were computed from temperature and DO profiles. First, measurements collected at depths less than or equal to 0.5 m were excluded to minimize the effects of surface warming. In some profiles, duplicate measurements of DO and/or temperature were collected at each depth, and in these cases, the average was used in computations. EPA used only profiles with measurements collected from at least half of the possible 1-m increments in the final analysis.

The upper boundary of the metalimnion was identified as the shallowest depth at which the temperature gradient exceeded 1 °C/m (excluding the surface layer) (Figure 8) (Wetzel 2001). DO_m for each lake profile was computed as the mean of DO measurements estimated at all 1-m increments deeper than the upper boundary of the metalimnion. That estimate of DO_m necessarily includes some measurements in the metalimnion, which might increase the estimates of DO_m relative to studies that can focus only on the hypolimnion. In the NLA data set, the upper boundary of the metalimnion could be determined for most profiles. In contrast, many lakes in the NLA data set were too shallow to maintain a hypolimnion with small vertical temperature gradients (Jones et al. 2011), and therefore, no approach for consistently defining the hypolimnion for all lakes was available (Quinlan et al. 2005). Furthermore, inclusion of the

metalimnion was consistent with the assumption that taxa can use this transitional region as a refuge from warmer temperatures in the mixed layer (Klumb et al. 2004). The depth of water below the thermocline was computed as the difference between the maximum depth recorded for each lake and the mean depth of the upper boundary of the metalimnion. Chl *a* and DOC measurements from each lake were also used in the analysis. Prior to statistical analysis, all measurements were standardized by subtracting their overall mean values and dividing by the standard deviation. This standardization had no effect on the final model results, but helped the Bayesian models converge more efficiently (Gelman and Hill 2007).

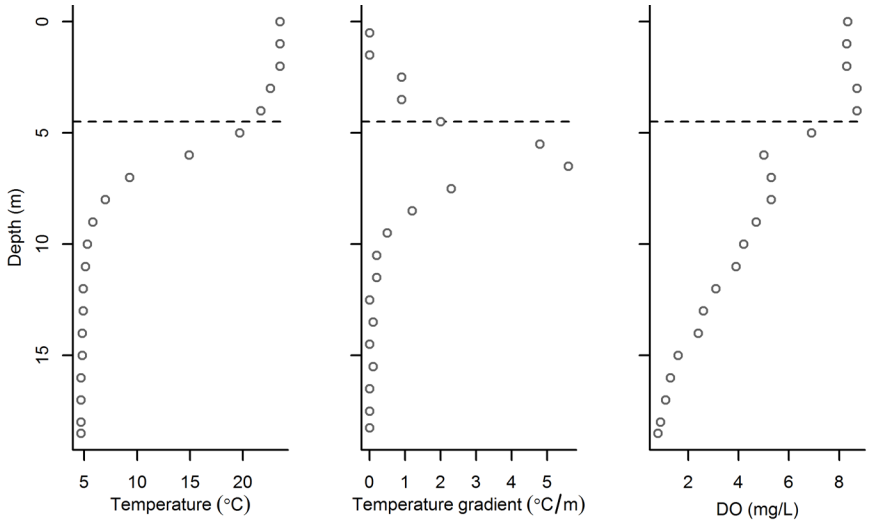

Figure 8. Illustrative examples of depth profiles of temperature, temperature gradient, and DO. *Dashed horizontal line*: estimated depth of the bottom of the epilimnion.

3.2.2.2 Statistical analysis

EPA modeled the decrease in DO_m as a linear function, an approximation that is appropriate for DO_m concentrations higher than approximately 2 milligrams per liter (mg/L) (Burns 1995). This threshold reflects experimental evidence indicating that the rate of decrease of hypolimnetic DO is constant at relatively high ambient concentrations of DO, but can be affected by DO concentrations near zero (Cornett and Rigler 1984). The linearly decreasing function also precludes the possibility of episodic mixing events that transport DO from shallow waters to deeper depths of the lake. In some lakes, those mixing events are rare, but in other lakes (e.g., cold polymictic lakes), they might occur frequently. In the latter group of lakes, the model predicts DO_m during extended periods of still weather, and the associated criteria would protect

aquatic life in those scenarios. Below, the statistical model is first described followed by a description of the approach for addressing DO_m measurements less than 2 mg/L.

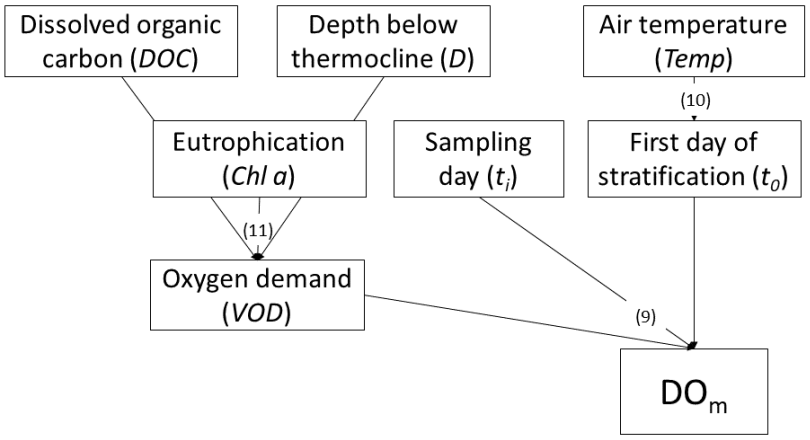

Figure 9. Schematic of hypoxia model. *Numbers in parentheses* refer to equation numbers in the text.

NLA data were fit to the following model equation:

$$E[DO_{m,i}] = DO_{0,j[i]} + VOD_{j[i]}\left(t_i - t_{0,k[i]}\right) \quad (9)$$

where $DO_{0,j[i]}$ is the value of DO_m at the start of spring stratification in lake *j* corresponding to sample *i*, and volumetric oxygen demand (VOD_j) is the net imbalance in the volumetric oxygen budget for lake *j*, expressed as mg/L/day of DO (Burns 1995). That is, VOD estimates the rate of decrease in DO_m per day. t_i is the date that sample *i* is collected, and $t_{0,k[i]}$ is the date of the beginning of stratification for the lake-year *k* corresponding to sample *i*. Observed values of $DO_{m,i}$ were modeled as being normally distributed about the expected value, with a standard deviation of σ_1.

The first day of stratification (t_0) was not measured for any of the lakes, and the precise day on which stratification occurs for a given lake and year depends on local wind speeds, temperatures, and lake morphology (Cahill et al. 2005). Previous work in northern temperate dimictic lakes found that the first day of stratification could be modeled as a function of mean annual temperature (Demers and Kalff 1993), so EPA specified the following relationship for t_0:

$$t_{0,k} = b_1 + b_2 Temp_{j[k]} + e_k \quad (10)$$

where $Temp_{j[k]}$ is the mean annual air temperature at the location for lake *j* corresponding to lake-year *k*, and b_1 and b_2 are coefficients that are fit to the data. The published relationship in

Demers and Kalff (1993) provided initial estimates for b_1 and b_2, which were used to specify prior distributions for the two parameters. The error term e_k is included in the model because the first day of stratification varies substantially in different years for a given lake because of differences in weather. Data published by Demers and Kalff (1993) indicated that the standard deviation of residual error for this relationship was approximately 12 days, so this value was used to specify the prior distribution for the standard deviation of e_k.

The initial concentration of DO at the time of stratification, DO_0, was also not measured for any of the lakes. Deep water temperatures in many seasonally stratified lakes are determined by temperatures prior to initiation of stratification (Hondzo and Stefan 1993), and so, deep water lake temperatures at the time of stratification were approximated as the minimum annual air temperature at the lake location. Then, the saturated DO concentration at the minimum annual air temperature provided an estimate for DO_0. Minimum air temperatures less than 4 degrees Celsius (˚C) were set to 4 ˚C, corresponding to water temperatures when the lake surface begins to freeze (Demers and Kalff 1993).

Lake trophic status affects VOD because increased phytoplankton production in the epilimnion increases the quantity of organic material available for decomposition in the hypolimnion and in lake sediments (Hutchinson 1938). In many lakes, allochthonous sources also provide organic matter that fuels bacterial respiration and depletes oxygen in deep lake waters (Pace et al. 2004, Kritzberg et al. 2004). VOD has also been observed to decrease with increasing hypolimnion depth, a phenomenon attributed to a weaker overall influence of sediment oxygen demand as the volume of the hypolimnion increases (Cornett and Rigler 1980, Müller et al. 2012). Based on these mechanisms, EPA modeled VOD as a linear function of the long-term mean Chl *a* concentration and depth below the thermocline in the lake. To account for the effect of allochthonous organic matter, DOC was also included as a third predictor variable for VOD (Hanson et al. 2003, Cole et al. 2011). The model equation for VOD can then be written as follows:

$$E[VOD_j] = d_1 + d_2 \log\left(Chl_{mn,j}\right) + d_3 D_{mn,j} + d_4 \log\left(DOC_{mn,j}\right) \quad (11)$$

where d_1, d_2, d_3, and d_4 are model coefficients estimated from the data; $\log(Chl_{mn,j})$ is the long-term mean of the log-transformed Chl *a* concentration lake, *j*; $D_{mn,j}$ is the mean depth of the lake below the thermocline; and $\log(DOC_{mn,j})$ is the seasonal mean of log-transformed DOC concentration in the lake. Variability in VOD across individual lakes about the mean value

estimated from the predictor variables was modeled as a normal distribution. Because Chl *a* concentrations can vary substantially over the summer in a lake, the modeling approach used with the zooplankton model provided a distribution of possible long-term mean log(Chl_{mn}) values for each lake, given one or more instantaneous measurements of Chl *a* concentration. More specifically, seasonal mean log(Chl_{mn}) values for different lakes were modeled as a normal distribution as follows:

$$\log(Chl_{mn,j}) \sim Normal(\mu_{Chl}, s_{Chl,1}) \quad (12)$$

Then, individual log-transformed measurements from each lake were assumed to be drawn from a normal distribution with a mean value equal to the long-term mean as follows:

$$\log(Chl_i) \sim Normal(\log(Chl_{mn,j[i]}), s_{Chl,2}) \quad (13)$$

where Chl_i is the Chl *a* concentration measured in sample, *i*, associated with the mean $log(Chl_{mn})$ concentration in lake *j[i]*. (Note that Equations (12) and (13) are not shown in Figure 9.) Within-year variability of DOC and depth below the thermocline were substantially less than observed for Chl *a*, so long-term means for each of those parameters were estimated as the mean value of all available data for each lake. Weakly informative prior distributions were assigned to all parameters except for those that are noted above. Weakly informative prior distributions constrain parameter estimates away from extreme values, while allowing the data to determine the estimate for each parameter.

As noted earlier, DO_m approaches zero asymptotically over time and modeling that relationship with the linear model described above would introduce biases to the model. To account for the asymptotic relationship, EPA modeled samples with DO_m less than 2 mg/L with methods used for measurements that are below a known detection limit. That is, the samples were modeled as if their "true" DO_m values were unknown but their maximum values were 2 mg/L (Gelman and Hill 2007). This approach retained some information inherent in a sample with DO_m less than 2 mg/L (i.e., Chl *a*, lake depth, DOC, and sampling day are consistent with low DO_m), but allowed the use of linear relationships in the model to estimate the rate of DO depletion. More specifically, the model fits a linear trend in time to DO_m observed from lakes with similar Chl *a*, DOC, and depth. By assuming that measurements of DO_m less than 2 mg/L are unknown, the estimates of the linear relationship are more strongly determined by the higher DO_m concentrations, and samples with DO_m less than 2 mg/L exert a weak influence that is still consistent with the overall relationship. Retaining samples with DO_m less than 2 mg/L in the

model prevents biases that would be introduced by considering only lakes with relatively high DO_m.

3.2.2.3 Results

A total of 477 samples collected at 381 lakes were available for analysis. DO_m concentrations in 165 samples were less than 2 mg/L and were modeled as unknown values that were less than 2 mg/L. The asymptotic relationship can be seen in the plot of Chl *a* versus DO_m (Figure 10), in which DO_m decreases steadily up to a Chl *a* concentration of about 4 µg/L. At higher Chl *a* concentrations, the magnitude of the slope of the relationship between DO_m and Chl *a* decreases and approaches zero.

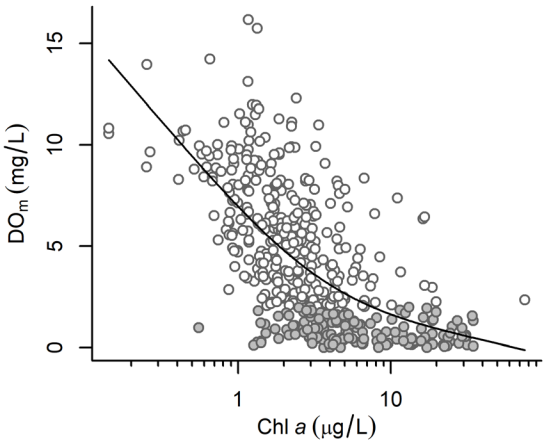

Figure 10. Chl *a* vs. DO_m. DO_m values. *Gray-filled circles:* values < 2 mg/L; *solid line*: nonparametric fit to the data shown only to highlight the asymptotic relationship.

The majority of the estimates for the first day of stratification ranged from day 30 to day 120 (Figure 11). In most lakes, the Demers and Kalff (1993) estimate for the first day of stratification was later than the value of t_0 estimated by the model. This systematic difference is consistent with the fact that most of the lakes considered in Demers and Kalff (1993) were located north of the mean latitudinal location of the NLA lakes. The strong association between the Demers and Kalff (1993) estimates and the current estimates indicates that the overall formulation of the model, in which stratification day is a function of mean annual temperature, is valid.

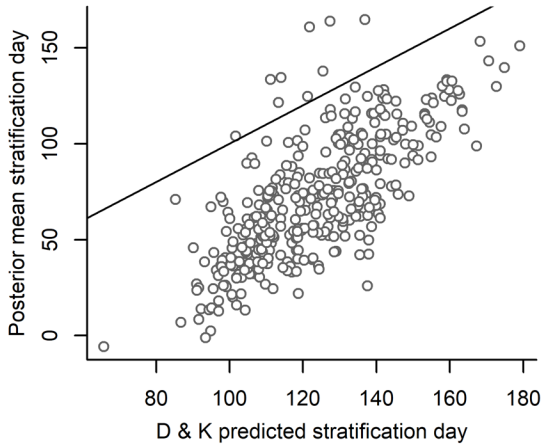

Figure 11. Demers and Kalff (1993) predicted stratification day vs. model mean estimate. *Solid line*: the 1:1 relationship.

Relationships estimated between DO_m and different predictors were consistent with the hypothesized effects of each of the predictors (Figure 12). DO_m decreased strongly with increases in DOC and Chl *a*, reflecting the increased organic material available in lakes with high concentration of the two parameters. Conversely, DO_m increased with increasing depth below the thermocline, consistent with observations in other studies. Substantial uncertainty is associated with the relationship between DO_m and day of the year, reflecting the inherent uncertainty in estimating the first day of stratification for different lakes.

The root mean square (RMS) error on model predictions for samples with DO_m higher than 2 mg/L was 1.5 mg/L. RMS error is defined as the square root of the average squared difference between predicted and observed values. Slightly greater residual variability in the observations about the mean predictions were observed at high values of DO_m (Figure 13).

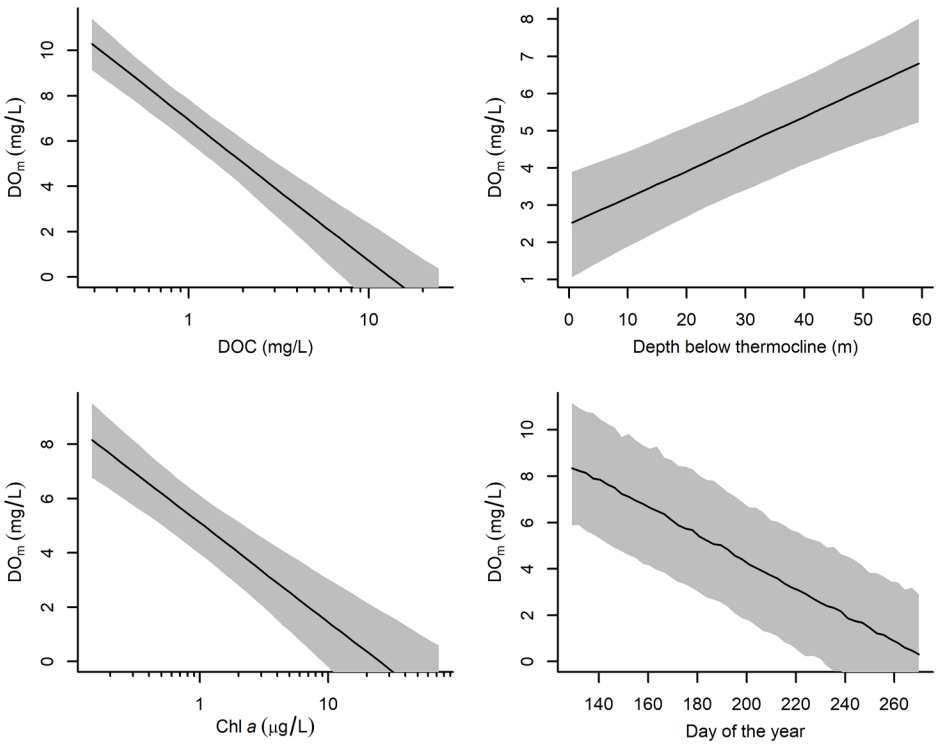

Figure 12. Relationships between individual predictors and DO_m, holding other variables fixed at their mean values. *Solid line*: mean relationship; *gray shading*: 90% credible intervals.

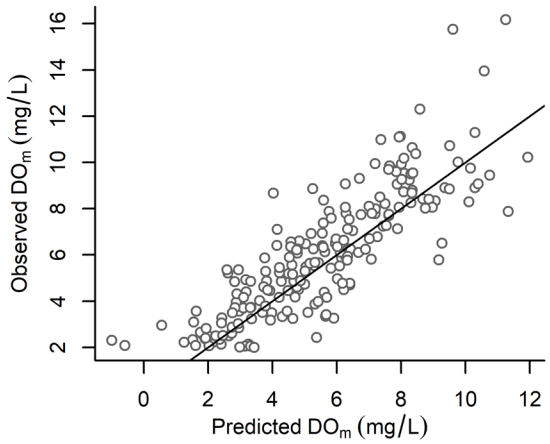

Figure 13. Model predicted DO_m vs. observed DO_m. *Open circles*: individual samples; *solid line*: 1:1 relationship.

The statistical model described for DO_m is consistent with the mechanisms of DO depletion in the deep waters of a lake, in which available DO below the thermocline is progressively depleted after the initiation of spring stratification. The estimated effects of eutrophication, DOC, and

lake depth on the rate of oxygen depletion were consistent with trends observed in other studies.

3.2.2.4 Chl a criteria derivation

As described earlier, warm temperatures in the shallow mixed layer of a lake act together with deep water hypoxia to constrain the available habitat for cool- and cold-water taxa. Therefore, to derive criteria based on deep water hypoxia, estimates of changes in water temperature over the course of the summer are required to identify periods of time during which mixed layer temperatures are too high for different taxa. Those periods of time then determine when deep water DO concentrations need to be sufficiently high to support different organisms.

Water temperature in the lake mixed layer depends on a variety of factors, including the local climate, solar insolation, lake morphology, and the day of the year (increasing in the spring and summer and decreasing in the fall). To identify temperatures in different lakes that were likely to limit available habitat for different fish, EPA first developed models to predict temperature in the shallow, mixed layer of different lakes. NLA data collected at all lakes in the conterminous U.S. were used to fit the model. At each lake, maximum temperature (excluding the top 0.5 m of the surface layer) observed in vertical profiles collected in each lake were modeled as a function of lake geographic location, elevation, and sampling day of the year with a generalized additive model (Wood 2006) of the following form:

$$E[T_i] = f_1 + f_2 Elev_{j[i]} + s(yday_i, df = 7) + s\left(Lat_{j[i]},\ Lon_{j[i]}, df = 30\right) \quad (14)$$

where E[T_i] is the expected value of the maximum temperature in the lake observed in sample *i*. $Elev_{j[i]}$ is the elevation of the lake, *j*, corresponding to sample *i*. The variable $yday_i$ is the day of the year that the sample was collected, and $Lat_{j[i]}$ and $Lon_{j[i]}$ are the latitude and longitude of the lake. The relationship between temperature and elevation was modeled as a simple linear relationship, characterized by two regression coefficients, f_1, and f_2. Relationships between lake temperature and sampling day and between lake temperature and location were modeled as nonparametric splines, represented in Equation 14 as *s(.)*, with the maximum degrees of freedom, *df*, as indicated. Observed values of T_i were assumed to be normally distributed about the modeled expected value.

Lake temperature generally decreased with increased latitude, as would be expected (Figure 14), but deviations from that latitudinal pattern were observed on the west coast of the U.S.,

where lake temperatures were substantially lower than lakes at a similar latitude in the eastern U.S. This trend likely arises from the moderating influence of the coastal waters on air temperatures. Lake temperatures in eastern Texas and Louisiana were warmer than lake temperatures at the same latitudes elsewhere. Lake temperatures decreased with elevation, as expected, and exhibited a unimodal pattern with sampling day, with maximum temperatures occurring on average on Day 204, or July 22 (Figure 15). Overall, the model predicted lake temperature with an RMS error of 1.9 ˚C.

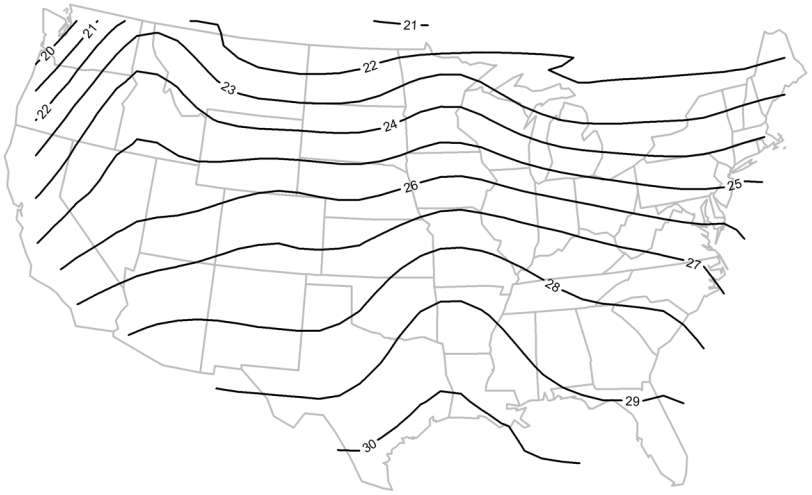

Figure 14. Contours of modeled mean lake temperature computed at the overall mean elevation and mean sampling day.

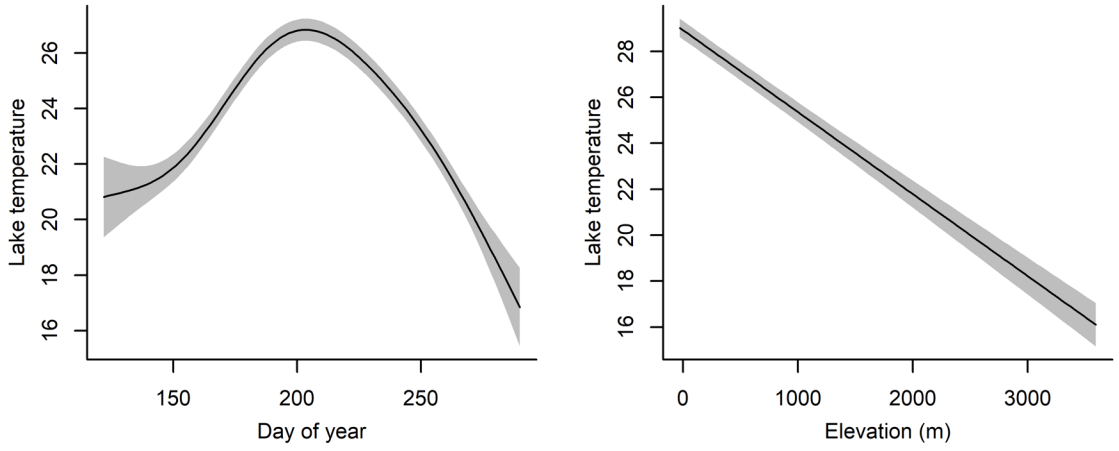

Figure 15. Relationship between lake temperature and sampling day (*left panel*) and elevation (*right panel*). Variables that are not plotted are fixed at their mean values. *Gray shading*: 90% confidence intervals; *solid lines* shows the mean relationships.

The pattern of temperature changes with time (see Figure 15) provides insight into the critical period during which the severity of deep water hypoxia can influence aquatic life in lakes. For most lakes, mixed layer temperatures increase in the spring and exceed critical temperatures for different species, at which point cool- and cold-water obligate species must move to deeper depths. Then, in the fall, decreasing mixed layer temperatures allow those species to move back to shallower waters. Models for DO_m indicate that, in dimictic lakes after the onset of spring stratification, DO_m decreases monotonically over time until fall turnover (see Figure 12). Therefore, the length of time between spring stratification and when mixed layer temperatures decrease below the critical temperature thresholds in the fall is a key factor for deriving a protective Chl *a* criterion.

EPA used documented temperature thresholds defined for cool- and cold-water fish as examples of critical mixed layer temperatures (Coker et al. 2001). For cool-water species, EPA identified an illustrative temperature threshold of 24 °C. Walleye, striped bass, and yellow perch are examples of lake fish that are members of that group (McMahon et al. 1984). For cold-water species, EPA identified an illustrative temperature threshold of 18 °C. Lake trout and cisco are examples of cold-water obligate species (Marcus et al. 1984, Jacobson et al. 2008). (Note: These references are only examples of the types of information that can be used to inform decisions regarding the critical temperature for different fish species and different fish life stages.) Then, given a lake's location and elevation, the lake temperature model predicts the day of the year that the mixed layer temperature would decrease below the critical temperatures. For cool-water species, mixed layer temperatures decreased below the critical temperature of 24 °C on days 210–260 (Figure 16), taking into account the fact that the dimictic lakes considered in this analysis are located in the northern half of the country (see Figure 7). Lakes in which mixed layer temperatures increased above 24 °C at some point during the year were predominantly located in the eastern U.S., as high elevations and climate in the western U.S. moderate lake temperatures. For cold-water species, mixed layer temperatures decreased below the critical temperature of 18 °C on days 220–280 (Figure 17). Temperatures in many lakes in the southeast part of the U.S. rarely decrease below the critical threshold in the summer, but those lakes also generally do not harbor cold-water fish.

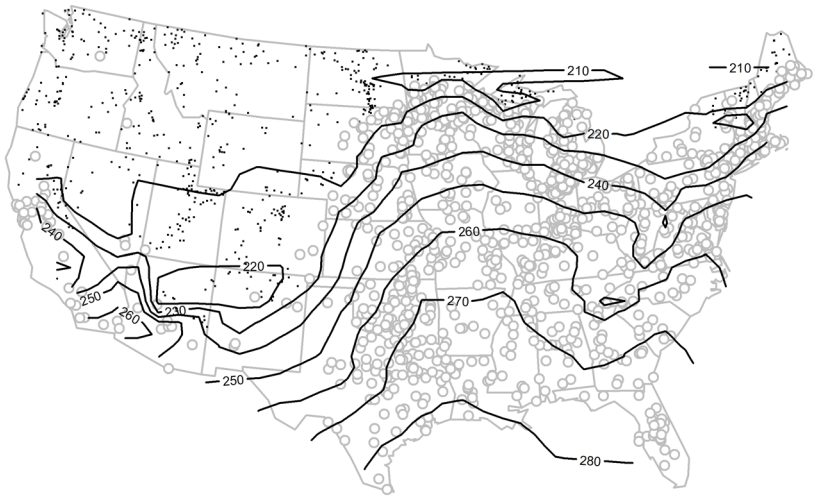

Figure 16. Days of the year that mixed layer temperatures decrease below the critical temperature for cool-water species. *Small dots*: lakes in which mixed layer temperatures never exceed 24 °C.

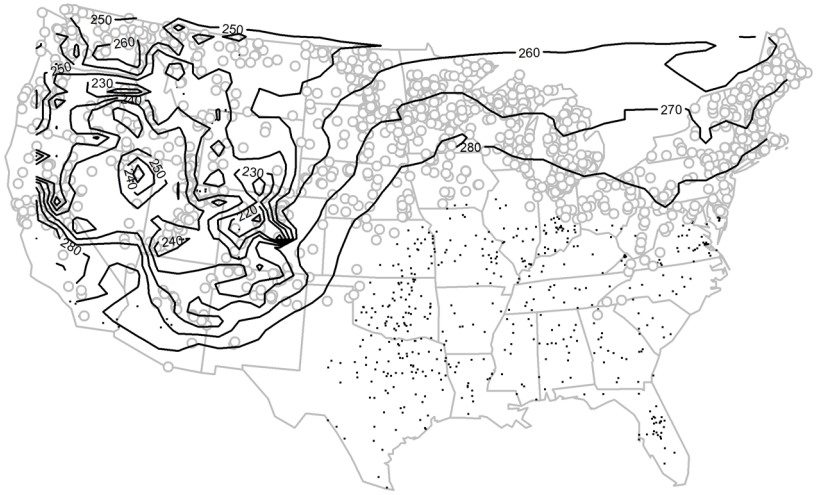

Figure 17. Days of the year that mixed layer temperatures decrease below the critical temperature for cold-water species. *Small dots*: lakes in which mixed layer temperatures do not decrease below 18 °C during the summer; *contours*: effects of large differences in elevation across lakes in the western U.S.

Criterion values for Chl *a* are calculated from the model equation for DO_m, rewritten here:

$$DO_m = DO_0 + [d_1 + d_2 \log(Chl_{mn}) + d_3 D + d_4 \log(DOC_{mn})](t - t_0) \quad (15)$$

Deep water DO concentrations depend not only on Chl *a* concentration, but also on the depth of the lake below the thermocline (*D*), DOC concentration (DOC_{mn}), and length of time that has elapsed since the establishment of stratification ($t - t_0$). A procedure for computing the day of the year, t_{crit}, at which mixed layer habitat is cool enough for different species to move to shallower water is also described above, highlighting the influence of lake location and elevation

as additional factors to consider. Based on these models, Chl *a* criteria for different lakes vary considerably depending on each lake's specific characteristics.

Prior to calculating a Chl *a* criterion, a threshold value for DO_m must be selected. Existing EPA recommendations specify that the 7-day mean minimum DO concentration should be at least 5 mg/L to support cold-water fish (US EPA 1986). This threshold is also consistent with DO concentrations that fish have been observed to avoid in field studies (Coutant 1985, Plumb and Blanchfield 2009). A thin layer of cool water with sufficient DO provides a critical refuge for fish during the warmest periods of the year, and fish have been observed to seek out those cool water refuges. Observations of fish in warm lakes during the summer have indicated that they will congregate in cold water refuges as shallow as 30 centimeters (cm) (Coutant and Carroll 1980, Snucins and Gunn 1995, Baird and Krueger 2003, Mackenzie-Grieve and Post 2006). Hence, maintaining a DO concentration of at least 5 mg/L at a depth of 30 cm below the thermocline can provide a sufficient refuge for certain fish species and be protective of aquatic life. To convert this condition to a value of DO_m, EPA considered a simplified case in which DO linearly decreases from saturated conditions above the thermocline (DO = 8.4 mg/L at 24 °C) to a concentration of zero at some deeper depth (Figure 18). The linear decrease in DO is consistent with a steady-state solution of the diffusion equation, assuming a constant eddy diffusivity (Stefan et al. 1995). Based on this DO profile and the requirement that DO is 5 mg/L at 30 cm below the thermocline, an illustrative threshold value for DO_m can be computed as 1.6 mg/L for a lake that is 2 m deep below the thermocline. That is, when the temperature profile is as depicted in Figure 18, depth-averaged DO computed for the water column below the thermocline is 1.6 mg/L. Other thresholds for DO_m specific to different species of fish and different depths can also be calculated. For example, the threshold value for DO_m for a lake that is 10 m deep below the thermocline would be 0.3 mg/L.

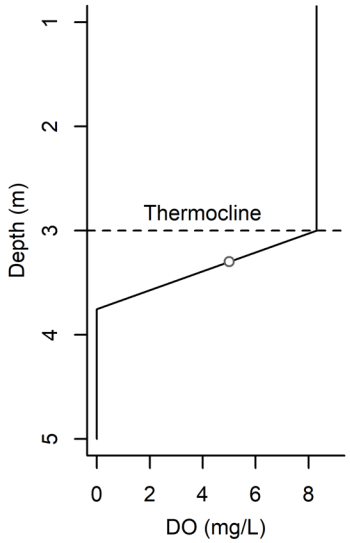

Figure 18. Simplified DO profile used to compute threshold for DO_m. *Open circle*: the targeted condition of DO at 5 mg/L, 30 cm below the thermocline.

The influence of different factors on Chl *a* criterion can be visualized by computing criteria at median values of all covariates and then examining changes in criteria that occur with the change in a single covariate. The relationship between Chl *a* and DO_m at median values for all other covariates are shown as solid lines in each panel of Figure 19. Lakes in which covariate values differ from the medians of the data set cause changes in the candidate Chl *a* criteria. For cool-water species, using the illustrative threshold temperature, the median number of days between spring stratification and release of the temperature constraint in the mixed layer was 135 days. The 75th percentile of this day range, corresponding to lakes in warmer climates, was 151 days, whereas the 25th percentile, corresponding to lakes in cooler climates, was 116 days. When the critical window for maintaining sufficient DO in the deeper waters decreases to 116 days, the corresponding Chl *a* criterion increases to 11 µg/L, whereas in lakes in which the critical window is 151 days long, the Chl *a* criterion is 2 µg/L (left panel, Figure 19).

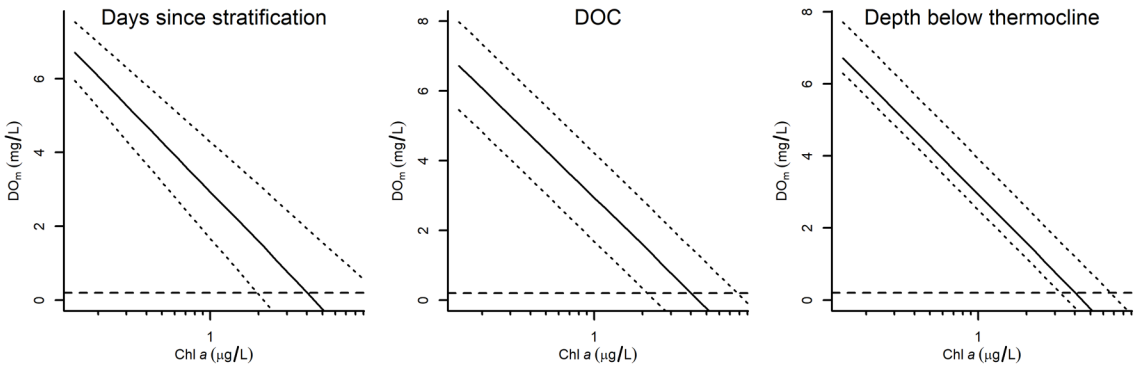

Figure 19. Effects of other predictors on Chl *a* criteria. *Solid lines*: relationship between Chl *a* and DO_m at median values for all other variables; *dashed line*: DO_m = 0.3 mg/L; *dotted lines*: 25th and 75th percentiles of days elapsed since stratification (*left panel*), 25th and 75th percentiles of mean DOC concentrations (*middle panel*), and depth below thermocline of 4 m and 20 m (*right panel*).

Similar ranges of criteria can be calculated for changes in DOC and the lake depth below the thermocline. The median concentration of DOC in the available data was 5 mg/L, but in lakes in which DOC is 3 mg/L (the 25th percentile of observed DOC in the data), the Chl *a* criterion increases to 8 µg/L; and in lakes in which DOC is 7 mg/L (the 75th percentile), the Chl *a* criterion decreases to 2 µg/L (middle panel, Figure 19). Finally, the median lake depth below the thermocline was 9 m. In a deeper lake, with 20 m of water below the thermocline, the Chl *a* criterion increases to 7 µg/L; but in a shallower lake, with only 4 m of water below the thermocline, the Chl *a* criterion decreases to 3 µg/L (right panel, Figure 19).

To better illustrate the possible range of criteria, EPA computed illustrative Chl *a* criteria for each of the dimictic lakes sampled in the NLA. Because those lakes represent a random sample of the population of lakes in the U.S., the resulting Chl *a* criteria are a representative distribution of criteria, providing insight into likely criteria for different types of lakes. For dimictic lakes harboring cool-water species (again, using the illustrative temperature threshold), the median Chl *a* criteria is 3.4 µg/L, and the range defined by the 25th and 75th percentiles is 1.3–10.6 µg/L. For lakes harboring cold-water species, using the illustrative temperature threshold, the median Chl *a* criterion is 1.8 µg/L, with a range of possible values extending from 1–7.6 µg/L.

In states where measurements of profiles of DO are available, these data can be readily modeled in conjunction with the national data (see Appendix B). In the example shown in Appendix B, modeling temporally resolved DO profiles from one state with the national data improved the precision of estimates of the first day of stratification. Because of this

improvement in model precision, the results of the combined state-national model are provided in the interactive criterion derivation tool.

The interactive tool used for estimating candidate Chl *a* criteria is provided at https://nsteps.epa.gov/apps/chl-hypoxia. With this tool, the user can specify lake physical characteristics that influence the relationship between Chl *a* and DO_m as well as management decisions about targeted conditions that affect the criterion.

Considerations: Lake physical characteristics. Lake physical characteristics that are specified include the lake location (latitude and longitude) and lake elevation. That information is converted to an estimate of mean annual air temperature and, coupled with the model results, these data provide an estimate of the date of spring stratification. Note, though, that this estimate applied most accurately to dimictic lakes, and estimates of the first day of stratification for other type of lakes (e.g., polymictic) are more uncertain and may require additional data. Other lake physical characteristics that are specified are lake depth below the thermocline and average lake DOC concentration, factors that influence DO_m.

Water quality management decisions that influence the calculated criterion include parameters that define fish habitat (i.e., the critical maximum temperature for fish species in the lake, the threshold DO concentration, and the depth of the summer refugia) and the certainty level.

Considerations: Fish habitat. The critical maximum temperature for fish species in the lake is used to calculate the average day of the year that temperature constraints are released in the epilimnion. That is, the annual temperature model (see Figure 15) is used to identify the date that fish can potentially move to oxygen-rich shallower waters. The threshold DO concentration for the fish (e.g., a DO concentration of 5 mg/L for cold-water fish) and the desired minimum thickness of the refugia (e.g., 30 cm) are used to compute the targeted condition for DO_m. That targeted value of DO_m is the minimum concentration required on the days prior to the release of temperature constraints.

Considerations: Certainty level. The certainty levels, as with other criteria, provide additional assurance that the calculated criterion is protective, based on the data and model uncertainty. For example, selecting the 50% certainty level implies that, at the estimated Chl *a* criterion, only 25% of predicted mean values of DO_m, based on the data, were less than targeted value. In statistical hypothesis testing, convention suggests that *p*-values of 1% or 5% are statistically significant results, which can also inform the selection of the percentile, but selection of the

certainty level as the basis for the criterion is ultimately a water quality management decision. More conservative certainty levels (e.g., higher percentiles) may be appropriate when applying this response in non-dimictic lakes in which the first day of stratification is more uncertain.

The interactive tool uses posterior simulation with model parameter distributions to predict the DO_m on the critical day prior to a release from temperature constraints in the surface layer for different Chl *a* concentrations. These model results can be used to help derive criteria for a specified threshold DO_m. Samples with covariate values similar to those selected by the user are highlighted in the provided plots in the app.

3.2.3 Microcystin Concentration

The model for microcystin relates Chl *a* concentration to a distribution of microcystin concentrations. By specifying different targets for microcystin concentration, this model can inform the derivation of criterion values for the protection of drinking water uses or recreational uses.

3.2.3.1 Statistical analysis

A network of relationships can be specified that reflects current understanding of the linkage between lake eutrophication (as represented by Chl *a*) and increased concentrations of microcystin in individual samples (Figure 20). At the bottom of the diagram, cyanobacterial biovolume is directly associated with microcystin. Cyanobacterial biovolume is then expressed as the product of total phytoplankton biovolume and the proportion of the biovolume that is cyanobacteria (i.e., the relative biovolume of cyanobacteria), which clarifies the nature of the relationship between Chl *a* and cyanobacterial biovolume. More specifically, Chl *a* is directly proportional to phytoplankton biovolume (repeating the relationship used in the zooplankton model) (Kasprzak et al. 2008), and, as Chl *a* increases, the relative biovolume of cyanobacteria has been observed to increase (Downing et al. 2001).

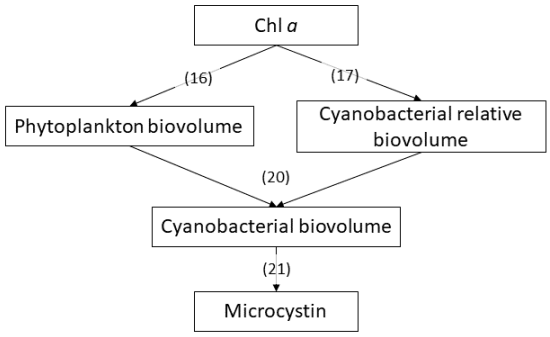

Figure 20. Schematic showing relationship between different variables predicting microcystin. *Numbers in parentheses*: refer to equation numbers in the text.

Each of the relationships in the network described above is expressed mathematically in the Bayesian network. First, phytoplankton biovolume, P_i, is modeled as being directly proportional to Chl *a* concentration (Chl_i), in sample *i*:

$$P_i = k_{c,i} Chl_i \tag{16}$$

The reciprocal of the parameter $k_{c,i}$ is the average amount of Chl *a* per unit biovolume of phytoplankton. Because the Chl *a* content of phytoplankton can vary with environmental conditions and assemblage composition, different values of this parameter are estimated for each sample, *i*. The overall distribution of the set of values for $k_{c,i}$ is assumed to be log-normal with a mean value of μ_k and a standard deviation of σ_k.

Exploratory analysis indicated that a quadratic function provided a reasonable representation of the relationship between the expected relative biovolume of cyanobacteria, p_c, and Chl *a* as follows:

$$E[logit(p_{c,i})] = f_1 + f_2 chl_i + f_3 chl_i^2 \tag{17}$$

where f_1, f_2, and f_3 are coefficients estimated from the data.

Because laboratory replicates of P_i and $p_{c,i}$ were available, uncertainty associated with measuring phytoplankton and relative biovolume of cyanobacteria was estimated as follows:

$$\log(Bm_j) \sim Normal(\log(B_{i[j]}), s_1) \tag{18}$$

$$logit(pm_{c,j}) \sim Normal(logit(p_{c,i[j]}), s_2) \tag{19}$$

where Bm_j and $pm_{c,j}$ are the laboratory measurements of phytoplankton biovolume and proportion cyanobacteria, respectively, and the index *j* maps replicate measurements to the corresponding estimate of the true value of the measurement for sample *i*. These laboratory replicates are assumed to be normally distributed about their respective estimates of the transformed sample means, with standard deviations of s_1 and s_s, respectively.

Cyanobacterial biovolume (*C*) can then be expressed as the product of the relative biovolume of cyanobacteria and total phytoplankton biovolume. After log-transforming, the expression is as follows:

$$\log(C_i) = \log\left(k_{c,i}\right) + \log\left(p_{c,i}\right) + \log(Chl_i) \quad (20)$$

where cyanobacterial biovolume in sample *i* is the sum of a log-transformed parameter k_c, the log-transformed cyanobacterial relative biovolume in the sample, and the log-transformed Chl *a* concentration.

The final component of the model relates cyanobacteria biovolume to microcystin. Initial exploration of the data indicated that microcystin increases at a rapid rate relative to cyanobacterial biovolume at high levels of cyanobacteria. At low levels of cyanobacteria, however, microcystin increases at a somewhat lower rate. To account for this change in rate, microcystin was modeled with a piecewise linear model as follows:

$$\log\left(\mu_{MC,i}\right) = g(\log\left(C_i\right)) \quad (21)$$

where the response variable in this relationship is $\mu_{MC,i}$, the estimated mean concentration of microcystin in sample *i*. The function *g*(.) is the piecewise linear function, which is characterized by four parameters: the intercept, d_1, and slope, d_2, of the first segment; the point along the gradient at which the slope changes, c_p; and the slope of the second segment, d_3.

The distribution of observed microcystin concentrations about the mean value was then modeled as a negative binomial distribution as follows:

$$MC_i \sim NB(\mu_{MC,i}, \varphi) \quad (22)$$

where MC_i is the microcystin observed in sample *i* and *NB(.)* is a negative binomial distribution with overdispersion parameter, φ. Because the negative binomial distribution specifies only nonnegative integer outcomes, before fitting the model, EPA multiplied microcystin measurements by 10 and rounded to the nearest integer. Microcystin measurements below the

detection limit of 0.1 µg/L were set to zero (Yuan and Pollard 2017). Weakly informative prior distributions were assigned to all parameters in the model.

3.2.3.2 Results

A total of 2,352 observations of microcystin, cyanobacterial and phytoplankton biovolume, and Chl *a* were available from the NLA data set for analysis. Those measurements were collected from 1,116 different lakes spanning the conterminous U.S. An additional 112 samples of laboratory replicates of phytoplankton and cyanobacterial biovolume measurements were available to quantify measurement variability.

Three different relationships were estimated in the national model: (1) Chl *a* and phytoplankton biovolume, (2) Chl *a* and cyanobacterial relative biovolume, and (3) cyanobacterial biovolume and microcystin. (The relationship between phytoplankton biovolume, cyanobacterial relative biovolume, and cyanobacterial biovolume required no statistical estimation.) The observed relationship between Chl *a* and phytoplankton biovolume was accurately represented as a line with a slope equal to 1 on log-log axes (left panel, Figure 21), similar to the relationship estimated in the zooplankton model.

Cyanobacterial relative biovolume exhibited an increasing relationship with Chl *a* (middle panel, Figure 21). The quadratic functional form allowed the model to represent the steepening of the relationship at higher concentrations of Chl *a*. Mean microcystin increased with cyanobacterial biovolume (right panel, Figure 21). The slope of the relationship increased at a cyanobacterial biovolume of 1.9 mm^3/L, but the 90% credible interval on the location of this changepoint ranged from 0.5 to 5 mm^3/L. At cyanobacterial biovolumes greater than the changepoint, the slope of the mean relationship was statistically indistinguishable from 1, whereas at cyanobacterial biovolumes less than the changepoint, the slope was 0.61, with the 90% credible interval ranging from 0.51 to 0.69. Overall, the credible interval about the cyanobacteria-microcystin relationship was narrow compared to those estimated for the Chl *a*-cyanobacterial relative biovolume relationship as shown.

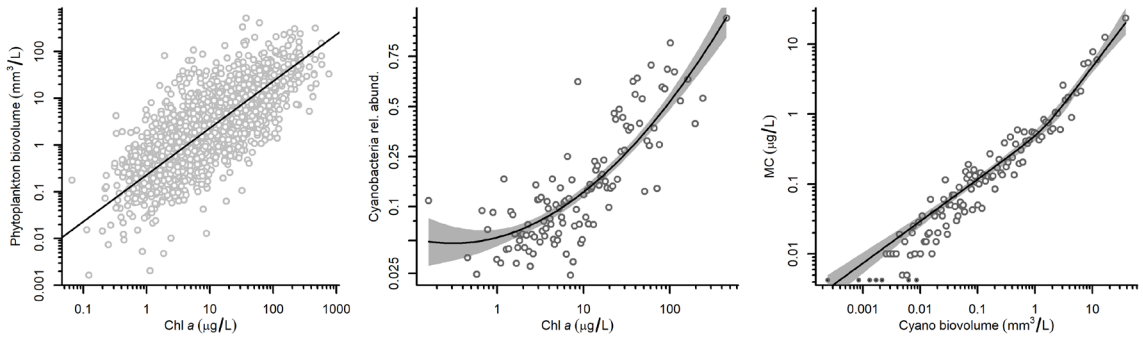

Figure 21. Modeled relationships for the microcystin model. *Left panel*: relationship between Chl *a* and phytoplankton biovolume; *open circles*: observed measurements of Chl *a* and phytoplankton biovolume; *solid line*: has a slope of 1. *Middle panel*: relationship between Chl *a* and cyanobacterial relative biovolume; *open circles*: average cyanobacterial relative biovolume in ~20 samples at the indicated Chl *a* concentration; *solid line*: estimated mean relationship; *gray shading*: 5th and 95th percentiles of the distribution of possible mean relationships (i.e., the 90% credible interval); *vertical axis*: has been logit-transformed. *Right panel*: relationship between cyanobacterial biovolume and microcystin; *open circles*: average microcystin in ~20 samples at the indicated cyanobacterial biovolume; *solid line*: estimated mean relationship; *gray shading*: 90% credible intervals about the mean relationship; *small filled circles*: Chl *a* bins in which microcystin in all samples was zero.

3.2.3.3 Chl a criteria derivation

Chl *a* criteria to protect recreational uses and drinking water sources can be derived from the estimated network of relationships by combining the model equations for total phytoplankton biomass, cyanobacterial-relative biovolume, and microcystin and the uncertainty inherent in each of the relationships (Figure 22). More specifically, based on a threshold concentration for microcystin and an allowable exceedance frequency of that threshold, Equation (22) can be used to compute the mean predicted microcystin that would be associated with these values. Then, Equations (20) and (21) can be used to calculate the Chl *a* concentration associated with this mean microcystin. This model is based on instantaneous measurements of Chl *a*, cyanobacterial biovolume, and microcystin. To relate instantaneous Chl *a* concentrations to a seasonal mean Chl *a* concentration, EPA computed the variance of Chl *a* concentrations within lakes over the summer sampling season using repeat visits included in the NLA data set. Then, the variance was used to estimate the probability of exceeding an instantaneous Chl *a* concentration, based on the seasonal mean Chl *a* concentration.

Threshold concentrations for microcystin have been published, and those targeted conditions can guide the use of the models to derive Chl *a* criteria. To protect sources of drinking water, the EPA uses a health advisory that recommends a threshold concentration for microcystin of 0.3 µg/L for preschool children less than 6 years old (US EPA 2015b). This short-term health

advisory does not include consideration of exposure to other sources (i.e., a relative source contribution term). Typically, EPA would use an ambient water quality criterion (developed under Section 304(a) of the CWA) as the endpoint for the protection of human health. The criterion would include consideration of exposure through drinking water and fish consumed, if both are designated uses for a waterbody. The criteria also provide estimates for only fish consumption. Because human health criteria are not available for microcystins, EPA recommends using the drinking water health advisory, recognizing that this threshold is an underestimate of risk for water bodies where consumption of fish is an important route of exposure.

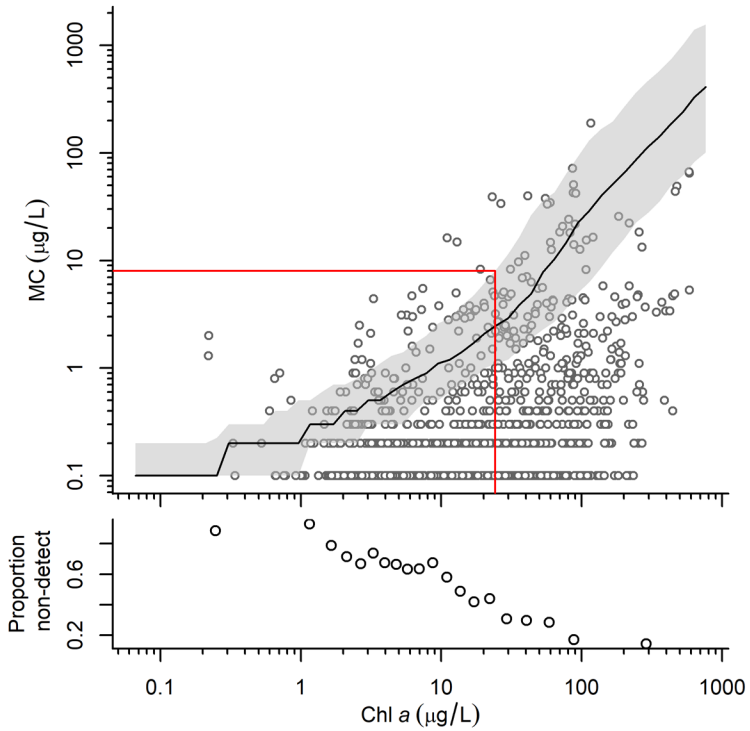

Figure 22. Example of derivation of Chl *a* criterion to protect recreational uses based on targeted microcystin of 8 µg/L and exceedance probability of 1%. *Top panel–open circles*: observed values of microcystin and Chl *a* for samples in which microcystin was greater than the detection limit; *solid line*: predicted microcystin that will be exceeded 1% of the time for the indicated Chl *a* concentration; *gray shading*: 25th and 75th percentiles of the distribution of possible mean relationships (i.e., the 50% credible interval); *solid vertical and horizontal line segments*: candidate Chl *a* criterion based on targeted microcystin. *Bottom panel*: proportion of samples for which microcystin was not detected in ~100 samples centered at the indicated Chl *a* concentration.

The drinking water health advisory applies to finished drinking water, but national ambient water quality criteria are designed to protect sources of drinking water. Human health criteria focus on water sources prior to treatment for two main reasons. First, the ability of treatment technologies to remove microcystin is too variable (Hoeger et al. 2005, Westrick et al. 2010, US EPA 2015c) for EPA to set a national recommendation for a protective ambient source water concentration that would yield a protective concentration after treatment. Second, consistent with the core statutory objective of the CWA Section 101(a) " to restore and maintain the chemical, physical, and biological integrity of the Nation's waters", the criteria are premised on the position that ambient waters should not be contaminated to a level where the burden of achieving health objectives is shifted away from those responsible for pollutant discharges and placed on downstream users such as drinking water utilities to bear the costs of upgraded or supplemental water treatment. EPA is aware that states or authorized tribes express water quality standards for protecting drinking water sources as either protecting the ambient source water before treatment or after treatment. If a state or authorized tribe applies the health advisory standard to drinking water after treatment, then they can account for the expected treatment in their facilities and select a higher microcystin concentration in the ambient source water that would result in the targeted microcystin concentration in the finished drinking water. Doing so will result in a concentration of Chl *a* in the ambient source water that will protect human health from the effects of microcystin in the finished drinking water. To protect recreational uses, EPA recommends a threshold concentration for microcystin of 8 μg/L to protect children (US EPA 2019). This threshold was based on incidental ingestion of water during recreation.

After selecting the designated use of interest, calculating the corresponding Chl *a* criterion requires two additional management decisions: selection of the allowable exceedance probability of the threshold and selection of a certainty level. These decisions are combined with a posterior simulation using the estimated distributions of the model parameters to estimate Chl *a* criteria.

Considerations: Allowable exceedance probability. The allowable exceedance probability can be interpreted directly in terms of environmental outcomes as the probability of observing a specified microcystin in a sample for a given seasonal mean Chl *a* concentration. For example, after accounting for model uncertainty by selecting a 50% certainty level, microcystin in lakes

with a seasonal mean Chl *a* concentration of 22 µg/L would be expected to exceed a threshold of 8 µg/L in 1% of samples (Table 3) (solid vertical line in Figure 22). With daily sampling, one interpretation of this result is that on average, microcystin would exceed the threshold 1 day out of every 100, so 1 day during the swimming season for many states would not support recreational use of the lake.

The frequency component of the recreational cyanotoxin criteria is specified in terms of excursions of the criterion magnitude during 10-day assessment windows (US EPA 2019), in which a water body is considered impaired for recreation when more than three excursions occur in 1 year. If we assume initially that daily samples are independent events, we can calculate the probability of at least one exceedance of the criterion magnitude in a 10-day window, and then compute a seasonal probability associated with greater than three excursions within all 10-day windows during a 100-day season. For example, if our single day exceedance probability is 0.05, there is a 62% chance that we will observe greater than three excursions during a 100-day season (Figure 23).

The initial assumption that daily samples of microcystin are independent from one another is conservative, as we would expect that a day with a high concentration of microcystin would be more likely to be followed by another day with high concentrations. That is, cyanobacterial blooms and the associated increases in microcystin concentration are likely to be clumped in time. This tendency for temporal autocorrelation may lower the computed seasonal probabilities, as we would expect somewhat fewer excursions during 10-day assessment windows if daily observations of elevated microcystin occur in groups. Overall, this information, or similar calculations tailored to conditions within a particular lake can further inform the selection of exceedance probability when deriving the candidate criterion.

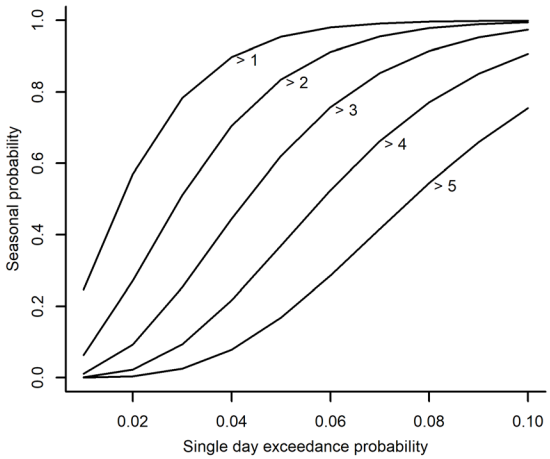

Figure 23. Probability of the indicated number of excursions observed in 10-day assessment windows during a 100-day season for different single day exceedance probabilities.

Considerations: Certainty level. The certainty level, as quantified by the credible interval, expresses the uncertainty in the model predictions of different exceedance probabilities. So, the shaded area in Figure 22 shows the range over which at least 50% of the possible curves would be located that describe microcystin concentrations that have a 1% probability of exceedance. Selection of a higher certainty level yields more conservative criteria in terms of model uncertainty. An interactive tool allowing the user to examine Chl *a* criteria associated with different combinations of microcystin threshold, probability of exceedance, and certainty level is available at https://nsteps.epa.gov/apps/chl-microcystin.

Table 3. Illustrative Chl *a* criteria (µg/L) for different exceedance probabilities using a 50% certainty level and a microcystin threshold of 8 µg/L**.**

Probability of exceedance	Candidate Chl *a* criterion (µg/L)
1%	22
5%	31
10%	39

3.2.4 Phosphorus-Chlorophyll *a*

A TP measurement is composed of P contained within different compartments, including P bound in phytoplankton, P bound to suspended sediment, and dissolved P (i.e., chemically dissolved P and P bound to particles small enough to pass through a filter) (Effler and O'Donnell 2010). In many lakes, much of measured TP is associated with phytoplankton, and so,

differences in phytoplankton biomass among lakes can be associated with differences in both Chl *a* and TP, yielding a strong correlation between the two (Lewis and Wurtsbaugh 2008). In other lakes, high concentrations of suspended sediment can contribute to TP and affect observed TP-Chl *a* relationships (Jones and Knowlton 2005). When TP-Chl *a* relationships are being estimated, lakes with high concentrations of suspended sediment show low Chl:TP ratios relative to the average pattern (Hoyer and Jones 1983, Jones and Knowlton 2005).

EPA modeled the relationship between TP and Chl *a* by explicitly accounting for the contributions of different compartments to observed TP, resulting in the positions of TP and Chl *a* in the model equation being reversed from the typical model formulations. The model explained variations in TP in various compartments, rather than explaining variation in Chl *a* (Yuan and Jones 2020b).

3.2.4.1 Statistical analysis

EPA specified a model that estimates contributions to TP from different compartments, where TP is modeled as the sum of contributions from dissolved P, P bound to nonphytoplankton sediment, and P bound in phytoplankton (Figure 24).

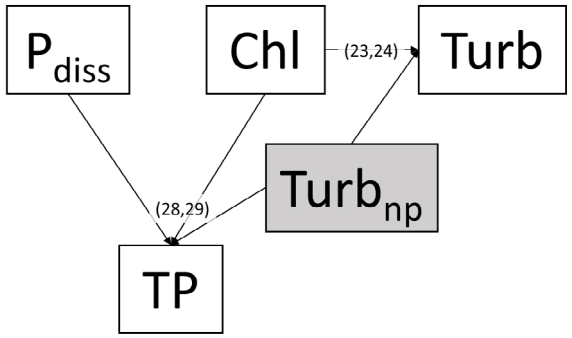

Figure 24. Schematic representation of compartment model for TP. P_{diss}: dissolved P; Chl: Chl *a*; Turb: total turbidity; $Turb_{np}$: turbidity attributed to nonphytoplankton sources. *Shaded box for* $Turb_{np}$: a variable inferred by the model; *numbers in parentheses*: refer to equation numbers in the text.

Direct measurements of nonphytoplankton sediment were not collected during the NLA. Instead, turbidity measurements were available that are associated with total suspended solids and include contributions from both nonphytoplankton and phytoplankton components. Because an estimate of nonphytoplankton sediment is needed to model TP, turbidity is modeled as the sum of two components: (1) turbidity that is directly associated with phytoplankton biomass, or autochthonous suspended sediment ($Turb_{aut}$) and (2) turbidity associated with all

other sources, or nonphytoplankton turbidity ($Turb_{np}$). The second component of turbidity includes turbidity associated with allochthonous sediment and sediment resuspended from the lake basin (Hamilton and Mitchell 1996). EPA modeled $Turb_{aut}$ as being directly proportional to Chl *a* (Jones et al. 2008), a measure of algal biomass and, therefore, the components of turbidity were expressed as follows:

$$E[Turb] = Turb_{np} + Turb_{aut} = Turb_{np} + fChl \quad (23)$$

where *E[Turb]* indicates that the model applies to the expected value of turbidity (Turb). The amount of $Turb_{aut}$ associated with each unit of Chl *a* is expected to vary with algal composition. For example, small phytoplankton species would tend to scatter light differently than larger species. Assuming that algal composition changes with trophic conditions (Godfrey 1982), the change in algal composition can be modeled by expressing the coefficient *f* as an unknown function of Chl *a*. Also, assuming that *f(Chl)* can be modeled as a power function ($f = bChl^m$), the product of *f(Chl)* and Chl *a* can be written as follows as $bChl^k$ without any loss of generality:

$$E[Turb] = Turb_{np} + f(Chl)Chl = Turb_{np} + bChl^k \quad (24)$$

where the exponent, *k*, is equal to *m*+1.

Exploratory analysis indicated that concentrations of $Turb_{np}$ varied with different lake characteristics, but the predictor that accounted for the most variability was lake depth. Therefore, 30 classes of lakes based on maximum depths were defined, and the value of $Turb_{np}$ within each of the classes was modeled as a log-normal distribution about a mean value specific to that depth class as follows:

$$\log(Turb_{np}) \sim Normal(\mu_{a,i},\ \sigma_a) \quad (25)$$

where $\mu_{a,i}$ is the mean value of log($Turb_{np}$) for depth class *i*, and σ_a is the standard deviation of the distribution of individual measurements of $Turb_{np}$. The set of values for $\mu_{a,i}$ was then assumed to be drawn from a single normal distribution as follows:

$$\mu_{a,i} \sim Normal(\mu,\ \sigma_\mu) \quad (26)$$

where μ and σ_μ are the mean and standard deviation of this distribution. The mean distribution loosely constrains the possible values of $\mu_{a,i}$, while allowing lakes with smaller amounts of data to "borrow information" from lakes with larger amounts of data (Gelman and Hill 2007).

Finally, sampling variability for Turb was assumed to be log-normally distributed as follows:

$$\log(Turb) \sim Normal(E[\log(Turb)], \sigma_T) \quad (27)$$

where *E[log(Turb)]* is the expected value of log(Turb) expressed in Equation (24).

EPA used results from the model for turbidity simultaneously to estimate contributions to different components of TP. Recall that TP is modeled as being composed of contributions from dissolved P (P_{diss}), P bound to suspended sediment, and P bound to phytoplankton. Based on this assumption, the following model equation can be written:

$$E[TP] = P_{diss} + g_1 Turb_{np} + g_2 Chl \quad (28)$$

where the concentration of P bound to nonphytoplankton suspended sediment is modeled as being directly proportional to $Turb_{np}$, and P bound to phytoplankton is modeled as being directly proportional to Chl *a*. The coefficient g_1 quantifies the P content of $Turb_{np}$, while the coefficent g_2 expresses P concentration relative to Chl *a* concentration. P content is expected to vary with the level of turbidity and the composition of the phytoplankton assemblage, so, similar to the model for turbidity, the coefficients g_1 and g_2 were allowed to vary as power functions of $Turb_{np}$ and Chl *a*, respectively. So, the final model equation can be written as follows:

$$E[TP] = P_{diss} + d_1 Turb_{np}^m + d_2 Chl^n \quad (29)$$

Exploratory analysis indicated that dissolved P was associated with lake depth, so, similar to $Turb_{np}$, different values of P_{diss} were estimated for each of 30 lake depth classes as follows:

$$\log(P_{diss,mn,i}) \sim Normal(\mu_{diss}, \sigma_{diss}) \quad (30)$$

where $P_{diss,mn,i}$ is the mean dissolved P concentration in lake depth class i, and the overall mean value of $\log(P_{diss,mn,i})$ is μ_{diss} with a standard deviation of σ_{diss}.

Exploratory analysis also indicated that the P associated with each unit of $Turb_{np}$ and Chl *a* (i.e., the values of the coefficients d_1 and d_2) varied most strongly with geographic location. Because of that trend, different values for these coefficients were estimated for different Level III ecoregions. Ecoregion-specific values for these parameters were assumed to be drawn from log-normal distributions as follows:

$$\log(d_{1,i}) \sim Normal(\mu_{d1}, \sigma_{d1})$$

$$\log(d_{2,i}) \sim Normal(\mu_{d2}, \sigma_{d2}) \quad (31)$$

where the index, *i*, refers to values of each parameter for different ecoregions.

Finally, sampling variation for TP was assumed to be log-normally distributed as follows:

$$\log(TP) \sim Normal(E[\log(TP)], \sigma_{TP}) \quad (32)$$

All the relationships described in this section on statistical analysis were fit simultaneously to the available data with a hierarchical Bayesian model (Stan Development Team 2016). Prior distributions for all model parameters were assumed to be weakly informative.

3.2.4.2 Results

Observations of turbidity were correlated with Chl *a*, and a distinct lower boundary in the scatter of data was evident (Figure 25). The model relationship defining this lower boundary can be computed by setting $Turb_{np}$ to zero in Equation (24). Then, after log-transforming, the equation can be written as $\log(Turb) = \log(b) + klog(Chl)$. In other words, when $Turb_{np}$ is negligibly small, the relationship between $Turb_{aut}$ and Chl *a* is a straight line in the plot of log(Chl) vs. log(Turb) (solid line in Figure 25). Deviations in sampled values above that line show the contribution of $Turb_{np}$ to the overall turbidity measurement. Mean values of *b* and *k* estimated from the model were 0.67 (0.62, 0.73) and 0.67 (0.65, 0.69) (90% credible intervals shown in parentheses). Based on the functional form that was assumed for the relationship between turbidity and Chl *a*, the contribution of phytoplankton to turbidity (i.e., $Turb_{aut}$/Chl *a*) was estimated as being proportional to $Chl^{-0.33}$. That is, as Chl *a* increases, the amount of turbidity associated with each unit of Chl *a* decreases, a trend that is consistent with a shift from small-bodied, diatom-dominated assemblages to colonies of cyanobacteria cells (Scheffer et al. 1997).

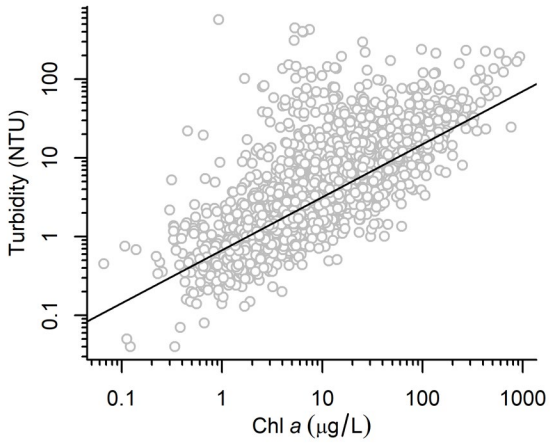

Figure 25. Turbidity vs. Chl *a*. *Solid line*: the limiting relationship between Chl *a* and turbidity when contribution of allochthonous sediment is negligible.

Estimates of $Turb_{np}$ and mean dissolved P both exhibited decreasing relationships with increasing depth (Figure 26). $Turb_{np}$ decreased from approximately 1.4 nephelometric turbidity units (NTU) in shallow lakes to nearly zero in deep lakes, while P_{diss} varied from approximately 2.6 µg/L in shallow lakes to 1.6 µg/L in deep lakes. Both of these relationships are consistent with a mechanism by which fine sediment from the lake bottom is likely to be collected in surface water samples in shallow lakes. In the case of P_{diss}, the trend indicates that measurements of dissolved and particulate components of TP are determined by filter size and P bound to sediment fine enough to pass through the filter contributes to estimates of dissolved P.

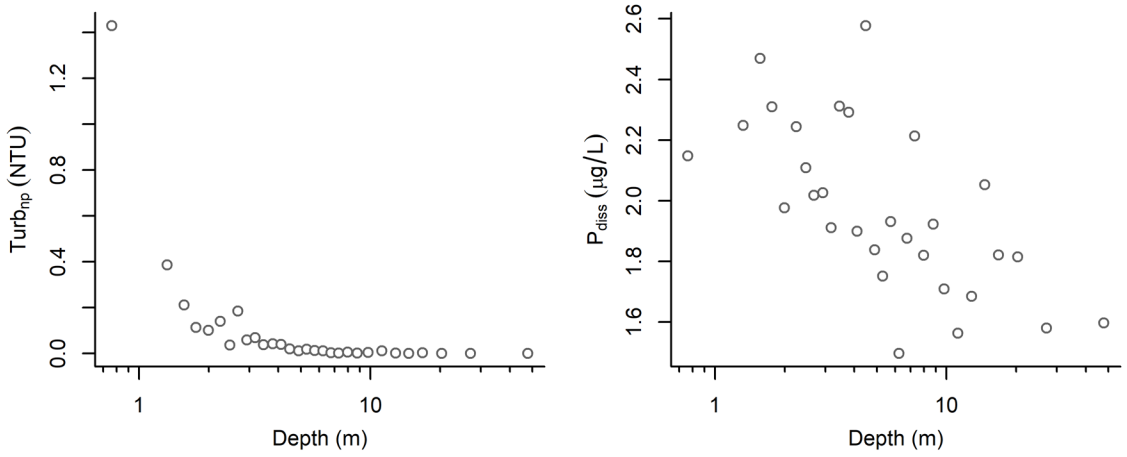

Figure 26. Relationship between $Turb_{np}$, P_{diss}, and lake depth. *Open circles*: mean estimate of parameter value in each of 30 lake depth classes.

The quantity of P bound to nonphytoplankton suspended sediment expressed by the coefficient d_1 exhibited substantial geographic variation (Figure 27). Coherent spatial patterns could be discerned in the variation of d_1 among different states, with relatively high levels of P content in the upper Midwest region of the country (e.g., Montana, North Dakota, and South Dakota) as well as in parts of the western mountains. Comparatively lower levels of P content were observed in the northeast region of the U.S. Mechanisms for these large-scale variations in P content are likely related to the underlying geology of soils in each region (Olson and Hawkins 2013). Values of d_2, the amount of P within phytoplankton, spanned a much narrower range than estimated for d_1, only ranging from 1.6 to 4.5 per unit of Chl *a*. The relative difference in regional variability in the coefficients indicates that spatial differences in the amount of P bound to nonphytoplankton suspended sediment account for more of the variability in TP-Chl *a* relationships than spatial differences in P within phytoplankton, and the amount of P residing in phytoplankton is relatively constant. The effects of differences in the amount of P bound to nonphytoplankton sediment can be taken into account by computing ecoregion-specific TP criteria.

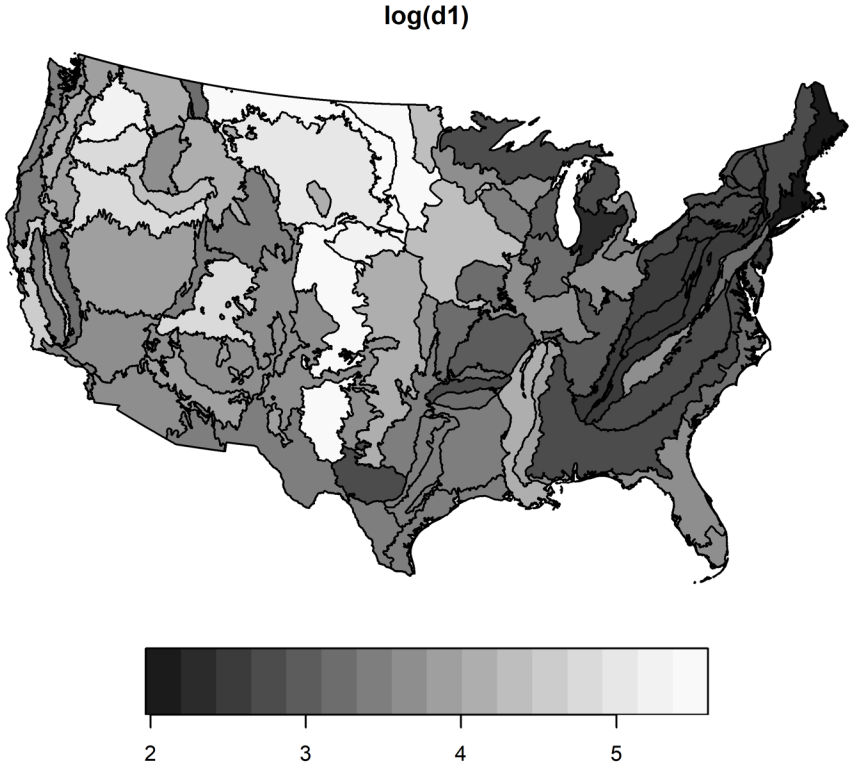

Figure 27. Ecoregion-specific values of $\log_e(d_1)$, P bound to nonphytoplankton suspended sediment.

Limiting relationships that estimate the P content of phytoplankton biomass and $Turb_{np}$ can also be calculated (Figure 28). For phytoplankton biomass, the limiting relationship is calculated by setting P_{diss} and $Turb_{np}$ in Equation (29) to zero, yielding the following log-transformed relationship: $\log(TP) = \log(d_2) + n\ log(Chl)$. Different values of d_2 were estimated for each ecoregion, but the distribution of those values is characterized by an overall mean value of 2.5 (2.0, 3.1), while the mean value of the parameter *n* was 0.87 (0.82, 0.92). The straight line based on the two parameter values represents P associated with phytoplankton biomass, as quantified by Chl *a*, and it tracks the lower limit of the observed data (solid line, right panel, Figure 28). As a limiting relationship, one would expect that the majority of values of TP would be greater than this line indicates, but variability associated with the value of d_2 causes some values of TP to fall below the limit.

For $Turb_{np}$, setting P_{diss} and Chl *a* to zero yields the following relationship: $\log(TP) = \log(d_1) + m\log\ (Turb_{np})$. The mean value of the coefficient d_1 was 31 (23, 40), and the value of the exponent *m* was 0.35 (0.32, 0.40) (left panel, Figure 28). Overall, the RMS error for predicting $\log_e$(TP) was 0.52 for the model.

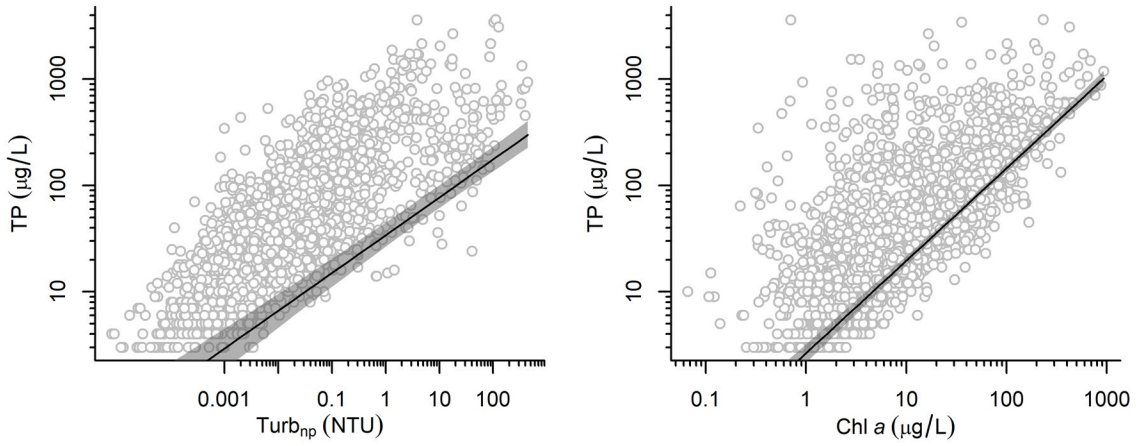

Figure 28. TP versus $Turb_{np}$ and Chl *a*. *Solid lines*: the limiting relationship between the indicated variable and TP; *gray shaded areas*: the 90% credible intervals about the mean relationship.

3.2.4.3 Phosphorus criteria

Two relationships between Chl *a* and TP that can be inferred from the TP model inform the derivation of TP criteria. First, the limiting relationship between Chl *a* and TP estimated from the model quantifies the amount of P that is bound to phytoplankton (see Figure 28). This relationship predicts TP concentration in samples in which suspended sediment and dissolved P

concentrations are very low and defines the *minimum* value of TP that is associated with a targeted Chl *a* concentration. This limiting relationship can also be interpreted as the Chl *a* yield of P (Yuan and Jones 2019) and could be used to predict the change in Chl *a* that would potentially result from a change in the amount of biologically available P in the water column (Reynolds and Maberly 2002).

A second relationship between TP and Chl *a* accounts for contributions from P bound to nonphytoplankton sediment. If lake depth is specified, then the relationship estimated between lake depth and nonphytoplankton sediment can be used to estimate an average contribution to TP from these other compartments in the water column (see Figure 26). The resulting relationship then provides an estimate of the *ambient* TP concentration one would expect to observe as a function of Chl *a*, and therefore, provides a TP criterion value.

The prediction of ambient TP that accounts for contributions from nonphytoplankton sediment provides an estimate of the mean TP concentration that one would expect to observe for a given Chl *a* (Figure 29). As such, this ambient TP concentration provides a criterion. (Illustrative examples for TP criteria are shown in Table 4.) Note that contributions of P_{diss} are not included in predictions of ambient TP criteria. In many lakes P_{diss} is composed of more biologically available forms of P (e.g., soluble reactive P), and so, concentrations of P_{diss} should be near zero in lakes in which reductions in P loading would be expected to influence phytoplankton abundance.

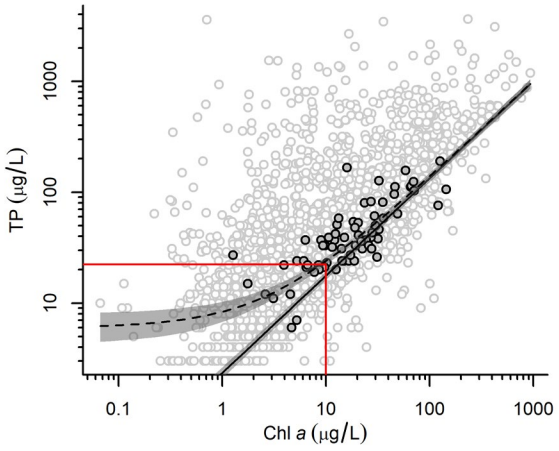

Figure 29. Example of deriving TP criteria for a Chl *a* target of 10 µg/L for data from one ecoregion (Southeastern Plains). *Open circles*: all data; *filled circles*: data from the ecoregion; *solid line*: limiting TP-Chl *a* relationship from compartment model; *dashed line*: ambient TP-Chl *a* relationship taking into account contributions from nonphytoplankton sediment for a 3-m deep lake; *solid horizontal and vertical line segments*: Chl *a* target and associated TP criterion; *shaded areas*: 80% credible intervals.

Table 4. Illustrative example of TP criteria corresponding to data shown in Figure 29. Example TP criteria for illustrative Chl *a* targets. TP criteria calculated for a 3-m deep lake.

Chl *a* target	80% certainty level	50% certainty level
10 µg/L	21	22
15 µg/L	28	30

The interactive tool for computing different TP criteria associated with Chl *a* is available at https://nsteps.epa.gov/apps/tp-tn-chl. This tool allows the user to specify the targeted Chl *a* concentration and the physical characteristics of the lake.

Considerations: Targeted Chl *a* concentration. The targeted Chl *a* concentration is the final criterion value derived for the lake(s) of interest after consideration of the different designated uses.

Considerations: Lake characteristics. Users can select the lake depth to be used when computing TP criteria. The coefficients d_1 and d_2 characterize the amount of P associated with nonphytoplankton suspended sediment and phytoplankton, respectively, and these coefficients vary among ecoregions (Figure 27). Therefore, users also can select an ecoregion for computing TP criteria. Data selected for an ecoregion are highlighted in the provided plots.

Considerations: Certainty level. Users can select a certainty level (as quantified by the credible interval) to account for the effects of model uncertainty on the calculated criteria. Basing criteria on the lower bound of the credible interval provides additional assurance that the calculated criterion is protective, given the data and model uncertainty. For example, selecting a certainty level of 50% dictates that the 25th percentile of the distribution of mean relationships is used to compute the lower bound of the envelope of possible relationships. A criterion based on this lower bound implies that only 25% of predicted TP concentrations at the selected Chl *a* concentration were less than the criterion value. In statistical hypothesis testing, convention suggests that *p*-values of 1% or 5% (corresponding to certainty levels of 99% and 95%, respectively) are statistically significant results. Those practices can also inform the selection of the percentile, but selection of the certainty level as the basis for the criterion is ultimately a water quality management decision.

3.2.5 Nitrogen-Chlorophyll *a*

Similar to the model for TP, each TN measurement is composed of N contained within three compartments: N bound in phytoplankton, dissolved inorganic N (i.e., nitrate, nitrite, and ammonia), and dissolved organic N (DON). Unlike the TP model, exploratory analysis indicated that the N content of inorganic suspended sediment was negligible (Yuan and Jones 2019).

3.2.5.1 Statistical analysis

Field measurements of the difference between TN and dissolved inorganic nitrogen (DIN = NO_x + ammonia) were modeled as follows:

$$E[TN - DIN] = f_1 Chl^{k1} + DON = f_1 Chl^{k1} + f_2 DOC \quad (33)$$

where variations in the observations of total N minus dissolved inorganic N (*TN-DIN*) are attributed to two compartments: N bound in phytoplankton, modeled as $f_1 Chl^{k1}$ and DON. Exploratory analysis indicated that DON was closely associated with DOC, as they often originate from the same watershed sources (Berman and Bronk 2003), so the concentration of DON was modeled as being directly proportional to DOC.

As with the TP model, exploratory analysis indicated that the parameters f_1 and f_2 varied most strongly with geographic location. Because of those trends and to facilitate the use of this model with local data sets, different values of f_1, and f_2 were specified for each Level III ecoregion:

$$\log(f_{1,i}) \sim Normal(\mu_{f1}, \sigma_{f1})$$
$$\log(f_{2,i}) \sim Normal(\mu_{f2}, \sigma_{f2}) \quad (34)$$

where the parameters μ_{f1} and μ_{f2} estimate the mean values of the distribution of f_1 and f_2 while σ_{f1} and σ_{f2} estimate the standard deviations.

The sampling distribution of TN-DIN was assumed to be log-normally distributed as follows:

$$\log(TN - DIN) \sim Normal(E[\log(TN - DIN)],\ \sigma_{TN}) \quad (35)$$

where σ_{TN} is the standard deviation of observed values of log(TN-DIN) about their expected value.

3.2.5.2 Results

A total of 2466 samples collected from 1875 lakes were available for analysis. Values for the coefficient, f_1, quantifying phytoplankton N content ranged from 11 to 43 in different ecoregions

with an overall mean value of 18.3 (14.9, 22.3). The values estimated for f_2 spanned a greater range among ecoregions with a minimum value of 35 and a maximum value of 103. The overall mean value of f_2 was 64.9 (61.0, 68.9). The broad range in values of f_2 indicates that strong differences exist among different locations regarding the nature of the relationships between DOC and DON. The mean value of the exponent, *k1*, was 0.90 (0.86, 0.94).

To visualize the variability in phytoplankton N among ecoregions, the concentration of N bound in phytoplankton at the overall mean Chl *a* concentration of 9.3 µg/L is mapped (Figure 30). With the exception of one high value of 320 µg/L estimated for the Sand Hills, Nebraska ecoregion, N-content of phytoplankton exhibited only small variations among ecoregions. N content ranged from 83 – 185 µg/L with a median value of 136 µg/L. Coherent spatial patterns in the N-content of phytoplankton were not evident.

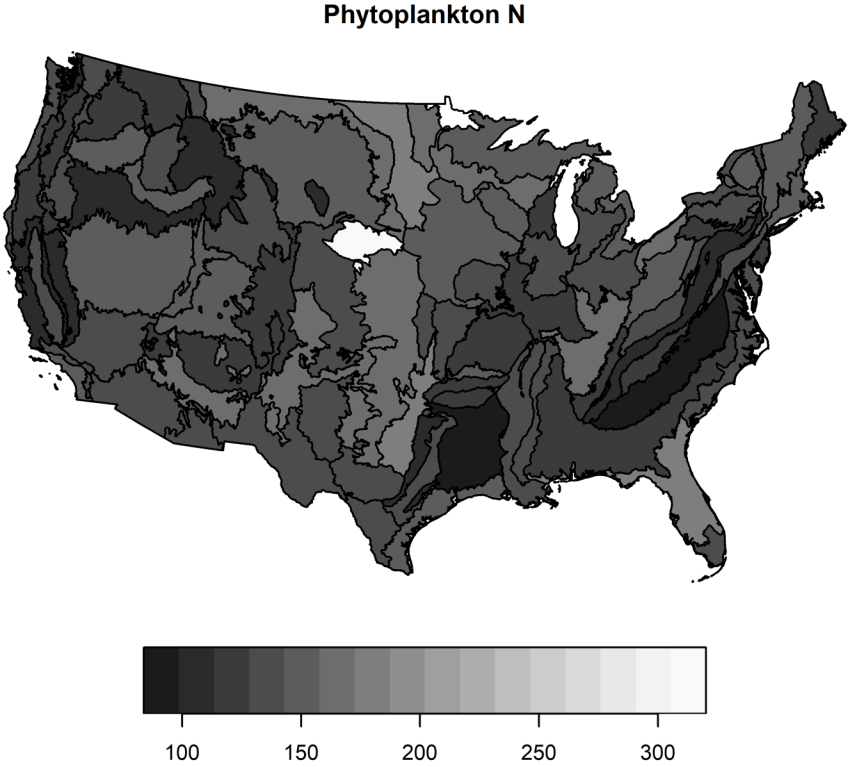

Figure 30. Variation in the concentration of N bound in phytoplankton among Level III ecoregions at the overall mean Chl *a* = 9.3 µg/L. Gray scale shows N concentrations in µg/L.

Estimated DON concentrations at the overall mean DOC concentration of 5.6 mg/L ranged from 194 – 570 µg/L with a median concentration of 365 µg/L (Figure 31). Variations in DON among ecoregions were substantially greater than observed for phytoplankton N. Spatial patterns were

also evident, with higher concentrations of DON in the upper Midwest regions of the U.S. and lower concentrations in the mountains in the western and eastern regions of the country.

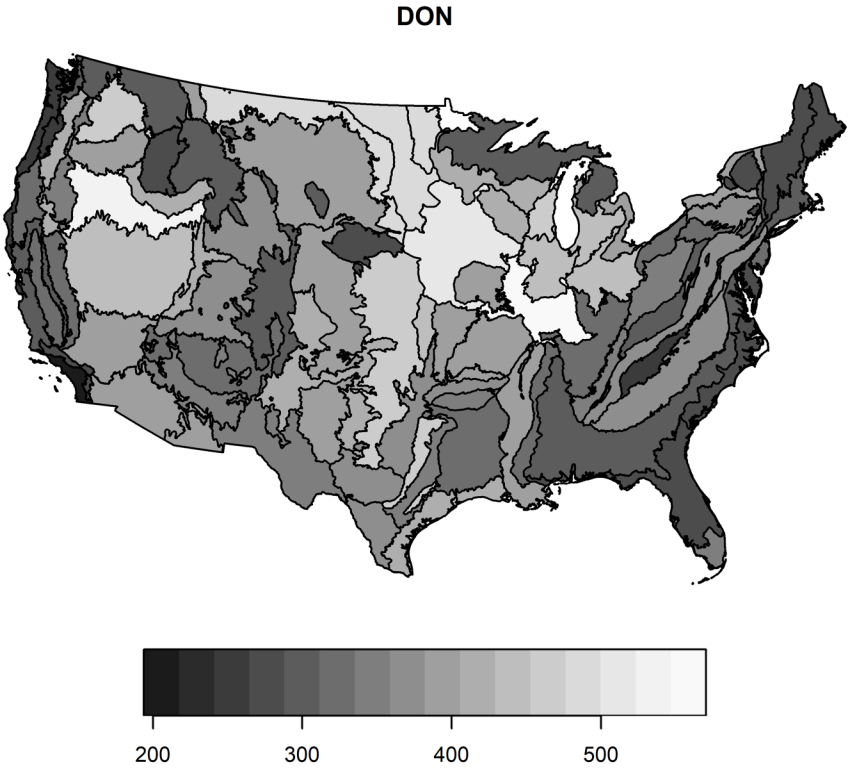

Figure 31. Variation in DON among Level III ecoregions at an overall mean DOC = 5.6 mg/L. Gray scale shows N concentrations in µg/L.

EPA calculated limiting relationships that estimate the N content of phytoplankton biomass with a procedure identical to that used for TP (Figure 32). In this case, the limiting relationship was calculated by setting the contribution from DON in Equation (33) to zero, yielding the following log-transformed relationship: $\log(TN - DIN) = \log(f_1) + k\ log(Chl)$. The straight line based on those two parameter values represents N associated with phytoplankton biomass, as quantified by Chl *a*, and it tracks the lower limit of the observed data (solid line, left panel Figure 32).

Similarly, setting DIN and Chl *a* to zero in Equation (33) yields the following limiting relationship for DON: $\log(TN) = \log(f_2) + \log(DOC)$ (solid line, right panel Figure 32). The mean value of f_2 indicates that, on average, the concentration of DON was 0.065 times that of DOC. Overall, the RMS prediction error for $\log_e$(TN-DIN) was 0.37.

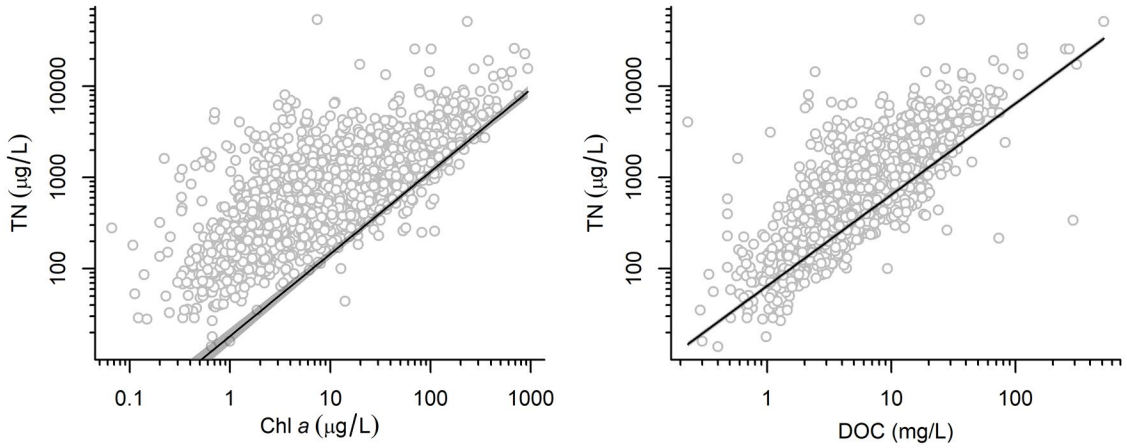

Figure 32. TN-DIN vs. Chl *a* and DOC. *Solid lines*: the limiting relationship between each variable and TN DIN; *shaded area*: the 95% credible intervals about this mean relationship.

3.2.5.3 Nitrogen criteria

The prediction for the ambient concentration of TN-DIN accounts for the increase in TN-DIN one would expect with increased Chl *a*, but also includes contributions from DON (as estimated by DOC) in the lake. Mean predictions for TN-DIN can be computed for different values of Chl *a* that include average contributions from other sources of N in the water column. The value of this *ambient* TN-DIN concentration that is associated with a targeted Chl *a* concentration then provides a criterion for TN-DIN (Figure 33, Table 5).

Criteria for N concentrations are commonly expressed in terms of TN rather than TN-DIN. To convert a criterion for TN-DIN to a criterion for TN, the availability of DIN for phytoplankton uptake can be considered. More specifically, the components of DIN (NO_x and ammonia) are easily assimilated by phytoplankton and, when excess concentrations of DIN are observed in a lake, it may indicate that factors other than N availability are limiting phytoplankton growth. Therefore, controlling phytoplankton growth by reducing available N would first require that DIN concentrations are reduced to near zero and, when that occurs, criteria expressed for TN-DIN would be the same as those for TN. Furthermore, examination of NLA data indicated that DIN concentrations were below the detection limit in 72% of samples, so TN-DIN was equivalent to TN in most samples. Hence, in most cases TN monitoring data can be assessed relative to TN-DIN predictions from the criterion models.

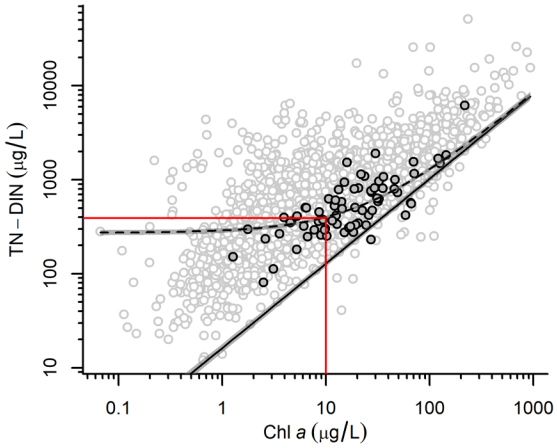

Figure 33. Illustrative example of deriving TN criteria for a Chl *a* target of 10 µg/L for one ecoregion (Southeastern Plains). *Open circles*: all data; *filled circles*: data from selected ecoregion; *solid line*: limiting TN-DIN vs. Chl *a* relationship from compartment model; *dashed line*: mean ambient TN-DIN vs. Chl *a* relationship taking into account mean DOC observed within the selected ecoregion: *shaded area*: 80% credible intervals; *horizontal and vertical solid line segments*: Illustrative Chl *a* target and associated TN criterion.

Table 5. Illustrative example of TN criteria corresponding to data shown in Figure 33.

Chl *a* target	**80% certainty level**	**50% certainty level**
10 µg/L	380	390
15 µg/L	440	450

The same interactive tool for computing different TP criteria also provides TN criteria associated with Chl *a* (https://nsteps.epa.gov/apps/tp-tn-chl). This tool allows the user to specify the targeted Chl *a* concentration, DOC concentration, and an ecoregion of interest. Finally, users can select the certainty level (or, credible interval) to account for the effects of model uncertainty on the calculated criteria. Data selected for an ecoregion are highlighted in the provided plots.

3.3 Duration and Frequency

The duration component of a water quality criterion is the length of time over which discrete water samples are averaged to assess the condition of the water body. The frequency component defines the number of times over a given time period that the specified magnitude of the criterion can be exceeded while the water body is still assessed as being in compliance with the criterion and maintaining designated uses. In conjunction with the magnitude of the criterion, these additional components define a water quality criterion.

Specification of duration and frequency components of numeric nutrient criteria is complicated by the fact that the ecological effects of elevated nutrient concentrations usually arise from a sequence of events. For example, higher nutrient concentrations increase the abundance of phytoplankton. Over time, higher abundances of phytoplankton then increase the amount of organic material in the deeper waters of a lake, and decomposition of the stored organic material can reduce the concentrations of DO. In this case, the duration and frequency of exceedance of a Chl *a* concentration in the mixed layer of the lake is related only indirectly to the ecological effect of decreased DO and the ultimate reductions in the amount of habitat for cool- and cold-water species. Contrast this example with the specification of duration and frequency of toxic pollutants, for which the length of time and frequency of exposure to the pollutant can be directly linked to effects on different organisms (e.g., mortality). A second consideration arises from the variability of environmental measurements, for which estimates of mean concentrations of Chl *a*, TN, and TP can only be estimated from a finite number of samples. So, when specifying duration and frequency components of the recommended numeric nutrient criteria, EPA considered both the timescale of the ecological responses and the statistical uncertainty in estimating mean values.

The recommended duration for Chl *a* criteria derived from the models described in this document is a growing season (typically summer) geometric mean value, consistent with the summary statistic used for Chl *a* in the stressor-response analyses. The geometric mean was selected to account for the fact that Chl *a* measurements are frequently log-normally distributed. EPA used seasonal mean Chl *a* concentrations integrated over the photic zone for analysis because timescales of ecological responses to increased nutrient concentrations are long. For example, as described earlier, some of the increase in deep water oxygen demand arises from accrual of organic material over long time periods while other oxygen demand arises from recently created organic matter that settles through the water column. Mean Chl *a* concentration in the lake is associated with mechanisms acting at both timescales, providing a measure of the average amount of organic material supplied by the photic zone. Similarly, systematic changes in zooplankton composition would be expected to occur at longer, seasonal timescales. For the microcystin model, the basic unit of analysis was an individual sample, in which the model predicted the probability of different microcystin concentrations in a sample, given the sample's Chl *a* concentration. When estimating the relationship for computing criteria, however, EPA computed probabilities of different individual Chl *a* concentrations as a function

of seasonal mean Chl *a* concentration, again linking seasonal mean Chl *a* concentration to the probability of deleterious effects. The long timescale of ecological response also supports the use of other durations that characterize average Chl *a* over long period of time. For example, in lakes with very long growing seasons, annual average Chl *a* may also be appropriate.

The unit of analysis for models relating Chl *a* to TN and TP concentrations was also the individual sample, in that TN and TP concentrations measured within a water sample were described as the sum of phytoplankton-bound N and P and other compartments in the sample containing those nutrients. Because the models are expressed as simple sums of components, each one remains applicable even if expressed in terms of seasonal averages. Hence, seasonal geometric mean Chl *a* criteria can be converted to seasonal geometric mean TN and TP criteria using the same model, and the recommended durations for TN and TP criteria are also seasonal mean values.

EPA recognizes that seasonal geometric mean concentrations of Chl *a*, TN, and TP calculated in different years can vary about their long-term means, and the frequency components of the criteria can be used to account for this variability. For example, in a year with particularly high precipitation one might observe higher than average loads of TP to downstream lakes. Similarly, in a year with longer than average periods of sunshine one might observe higher rates of accumulation of phytoplankton biomass and higher concentrations of Chl *a*. Sampling variability and within-year temporal variability also can cause large variations in estimated seasonal averages. Hence, in lakes in which long-term mean concentrations of Chl *a*, TN, and TP are below the criteria, some seasonal mean concentrations might still exceed the criterion magnitude. Variability in estimated seasonal mean concentrations can be addressed by estimating interannual and sampling variability and incorporating it into the expression of the criteria or in the assessment methods. More specifically, states may calculate adjusted criterion magnitudes that are associated with allowable frequencies of exceedance based on the observed variability of nutrient concentrations. For example, seasonal mean concentrations of TP would be expected to exceed a criterion magnitude that is equal to the long-term mean in approximately 50% of the years, whereas less frequent exceedances of a higher criterion magnitude would be expected. Appendices D and E provide examples of calculations that identify different combinations of criterion magnitudes and frequencies.

4 Characterization

In an ecological risk assessment, during the risk characterization phase, the results from the analysis are evaluated and the risk to ecological endpoints is described. In this section, general issues associated with applying the criterion models are considered, so a broader scope of topics is considered than is typically addressed during risk characterization. The topics include a discussion of other measures of effect and exposure that were not used in the criterion models, comparisons of current models with past models linking nutrients to Chl *a*, and limitations of the criterion models. Specific topics associated with deriving criteria in states and authorized tribes are also considered, including methods for incorporating local monitoring data into the national models, methods for developing statewide criteria, and the specification of duration and frequency components for the criteria.

4.1 Other Measures of Effect and Exposure

A variety of other measures of effect and exposure could be used for deriving nutrient criteria associated with each of the pathways described in Figure 1 and Figure 2. In selecting the responses for analysis, EPA considered (1) available data, (2) the current state of scientific understanding of each pathway, and (3) the degree to which a pathway and a response could be applied broadly to most lakes. For many possible measures of effect and exposure, data availability was a key consideration. For aquatic life, direct measurements of fish assemblage composition and biomass were not collected during the NLA, and the lack of those data limited the potential for considering several pathways such as evaluating alterations in fish assemblage composition because of reduced visibility. Lake benthic communities also exhibit changes along a eutrophication gradient (Vadeboncoeur et al. 2003), but none of those data were available. For recreational and drinking water source uses, the effects of other cyanotoxins (e.g., cylindrospermopsin, saxitoxin, anatoxin) might be important for certain lakes, but continental-scale data for those other cyanotoxins were not available at the time of this analysis. In certain lakes, cyanobacterial blooms have also been observed at depths below the surface layer (Jacquet et al. 2005), but observations of phytoplankton at those depths were not available. Similarly, organic matter generated by increased primary productivity can increase the concentrations of disinfection by-products during the drinking water treatment process (Graham et al. 1998, Galapate et al. 2001), and chemicals produced during blooms of certain

algal species can introduce unpleasant taste and odors to drinking water (Graham et al. 2010). However, continental-scale data pertaining to disinfection by-product precursors or taste and odor chemicals were not available.

Insufficient scientific understanding of a causal pathway also limited consideration of certain measures of effect and exposure. For example, scientific consensus is currently lacking on the precise level of cyanobacteria that is harmful to aquatic life. That information gap limited the utility of using cyanobacterial abundance as a final response measurement, despite the fact that increased cyanobacterial abundance occurs frequently with nutrient pollution (Dolman et al. 2012). (Note, however, that cyanobacterial abundance measurements quantify a key step in the model linking Chl *a* to microcystin.) Similarly, increased levels of cyanobacteria can cause rashes on people who contact the water (Pilotto et al. 1997, Zhang et al. 2015, US EPA 2015b), potentially affecting the use of a lake for recreation. However, precise quantitative relationships between the occurrence of rashes and cyanobacterial abundance are not currently available.

For certain measures of effect or exposure, data were available, but other factors limited the degree to which the response could be applied. For example, Secchi depth data were available in the NLA data set, and that measure of transparency could have informed an assessment of the aesthetic appeal of different lakes for recreation. That is, increased nutrient concentrations cause increases in the abundance of phytoplankton that reduce water clarity and decrease the aesthetic appeal of a lake (Carvalho et al. 2011, Keeler et al. 2015). Aesthetic considerations have been used by others as a basis of water quality criteria (Heiskary and Wilson 2008) and may be recommended for oligotrophic lakes in which maintaining historically high levels of water clarity is a management objective (see, for example, https://www.epa.gov/tmdl/lake-tahoe-total-maximum-daily-load-tmdl). However, the aesthetic expectations for the national population of lakes depends on geographic location (Smeltzer and Heiskary 1990), and user perception survey data at the continental scale of this analysis were not available. Similarly, reducing the frequency of phytoplankton blooms has been cited as a motivation for controlling nutrient loads (Bachmann et al. 2003), but aesthetic expectations regarding bloom frequency were not available at the national scale.

4.2 Incorporating State Data

State water quality managers are often interested in exploring relationships between environmental factors and biological responses using locally collected monitoring data. In many cases, leveraging knowledge from broader regional scales (e.g., national scale) can enhance local understanding. This document describes recommended numeric nutrient criterion models based on national data that link designated uses to Chl *a*, TN, and TP. The NLA data set provided a comprehensive set of measurements collected from large numbers of sites with identical protocols (US EPA 2011, Pollard et al. 2018), and the availability of consistent measures from lakes spanning broad gradients facilitated the calculation of accurate national estimates of relationships of interest. However, the number of samples is limited within the national data set that is available to estimate relationships within any single state, and uncertainty in estimating relationships specific to a single state is higher than that associated with the national models. In contrast, monitoring conducted by state agencies can yield more intensive temporal sampling over more sites, and hence, relationships estimated from those data can assist local management decisions within that state. Data collected at the state level, however, can be limited in the parameters that are measured, and the range of environmental conditions sampled is limited by conditions occurring within the state boundaries.

All the recommended criterion models described in this document are formulated to facilitate consideration of state data. State-specific values for certain coefficients in each model (e.g., Figure 34 in Appendix A) have been estimated, and local state, monitoring data can be used to refine the estimates of state-specific coefficients, while remaining consistent with national trends. Appendices A, B, and C discuss three examples of case studies in which state monitoring data have been combined with national data to refine recommended criteria. State monitoring data sets are each unique, and EPA is available to assist states in combining their monitoring data with the national models.

4.3 Existing Nutrient-Chlorophyll *a* Models

Empirically estimated relationships between TP and Chl *a* concentrations have provided a basis for lake water quality management for over four decades. This relationship was initially identified in Connecticut and Japanese lakes (Deevey 1940, Sakamoto 1966), and subsequently extended to a broad range of temperate lakes in the mid-1970s (Dillon and Rigler 1974, Jones

and Bachmann 1976, Carlson 1977). Those early analyses regressed Chl *a* on TP concentrations and reported similar coefficients showing the ratio of Chl:TP increased with lake trophic state. Over time, many studies have explored the veracity of that relationship and assessed sources of residual variation, testing the limits of applicability to different regions and lake types (Prairie et al. 1989, McCauley et al. 1989, Jones and Knowlton 2005, Filstrup et al. 2014b). Variations in the relationship have been attributed to differences in lake depth (Pridmore et al. 1985), TN:TP ratio (Smith 1982, Prairie et al. 1989, Molot and Dillon 1991), grazing by zooplankton and mussels (Mazumder 1994, Mellina et al. 1995), landscape characteristics (Wagner et al. 2011), and light limitation (Hoyer and Jones 1983, Knowlton and Jones 2000, Havens and Nürnberg 2004). Regional studies have evaluated the relationship as influenced by edaphic and climatic factors in locations such as Canada (Prepas and Trew 1983), Argentina, (Quirós 1990), the United Kingdom (Spears et al. 2013), and Europe (Phillips et al. 2008). Recently, lake classifications have improved the precision and accuracy of this relationship (Yuan and Pollard 2014).

As described in Sections 3.2.4 and 3.2.5, EPA reformulated the nutrient-chlorophyll models to account for variations in TP and TN, rather than in Chl *a*. The new models better account for variability in measurements of TP and TN and are consistent with an understanding of the components of TP and TN in the water column. The reformulated models cannot be directly compared with earlier studies, including those cited previously. Estimates of N and P content of phytoplankton, however, are consistent with values reported elsewhere (Yuan and Jones 2019).

4.4 Limitations and Assumptions

The recommended models for deriving numeric nutrient criteria are limited by the nature of the data that underlie the analysis. First, nutrient data for each lake consisted of samples collected at a single point, resulting in no information on within-lake spatial variability in nutrient concentrations being included in the analyses. Nutrient concentrations within particular lakes can vary considerably across different locations (Perkins and Underwood 2000), resulting in criteria based on samples collected at the deepest point or midpoint of the reservoir that might not be applicable to samples collected elsewhere. When deriving their criteria, states may specify assessment methodologies to collect samples from different locations in the same lake to address this issue and analyze those local data to account for spatial variability.

Similarly, nutrient and response data used in the current analysis were collected only in the summer, so monitoring data assessed with respect to these recommended criteria may also be limited to summer data. Nutrient concentrations in some lakes can vary considerably between summer and winter (Søndergaard et al. 2005), and states may specify assessment protocols to ensure that only data collected in the summer are compared with criterion concentrations. In other locations, much longer growing seasons exist, and annual average nutrient and Chl *a* concentrations are comparable to summer averages.

As noted earlier, most of the statistical criterion models described here combine the effects of spatial, temporal, and sampling variability and estimate a single value for each model that is applicable to all lakes in the data set. The components of variability, however, might differ across lakes and affect the resulting criteria. For example, spatial variability in complex, dendritic reservoirs can be much greater than in simple, circular lakes (Gloss et al. 1980). In most cases, local monitoring data can inform and potentially improve the parameter estimates both for specific locations and for groups of lakes. Segmenting lakes with complex morphology into discrete, more homogeneous areas may also help address issues with spatial variability.

The uncertainty estimated for each modeled relationship is associated with the number of samples used in the model, and consideration of sample size can affect the interpretation of the resulting criteria. For example, the number of NLA samples within a single Level III ecoregion can be small. The hierarchical structure of the model does improve the precision of model estimates in those ecoregions, but the precision of TP and TN criteria specific to ecoregions with small amounts of data could be further improved by including state monitoring data. Additional national-scale data such as that from the 2017 NLA may also be incorporated as they become available to improve model precision.

Recommended criteria based on the drinking water health advisories for microcystin incorporate some conservative assumptions that affect the final values. The recommended criteria are intended to reflect the ambient water quality conditions that protect a drinking water use before treatment. They do not, however, account for the varying levels of treatment a drinking water facility can implement to remove microcystin before generating finished drinking water, the condition of the water to which the cyanotoxin health advisories apply. As a precautionary step, a drinking water facility may implement treatment protocols that minimize the breakage of cyanobacteria cells (Chow et al. 1999, Westrick et al. 2010) which, in turn,

would minimize the release of intracellular microcystin into the treated water. EPA based the recommended models on the total microcystin present in the NLA samples, both dissolved in the water and within cyanobacterial cells, which necessitated the lysis of cyanobacterial cells prior to microcystin quantification. In contrast, breakage of cyanobacterial cells is a process that some drinking water treatments for cyanotoxins are designed to limit. Criteria based on the national models provide protective water quality conditions in the source water, but concentrations of microcystin that slightly exceed health advisory values can be further reduced in the finished drinking water through carefully engineered and operated source water treatment processes.

Recommended criteria derived using the models described here provide concentrations that, when exceeded, are associated with a loss of support for designated uses, but the models do not provide information regarding appropriate remediation actions. Indeed, among lakes in which the criteria are exceeded, appropriate remediation actions will likely differ. In some lakes, the magnitude of N loading from anthropogenic sources is small, while P loading is large, and cyanobacteria supply N to the system via fixation (Schindler et al. 2008). In those lakes, reductions in P loading might be the appropriate water quality management action. In other lakes, ample supplies of N from anthropogenic sources are available, and management actions might need to focus on reducing both N and P loading (Ferber et al. 2004). In some lakes, excess N in the form of inorganic nitrogen (NO_x or ammonia) is abundant, and the presence of high concentrations of DIN might provide insights into the effects of different management interventions. For example, DIN is readily taken up by phytoplankton, so the presence of large concentrations of DIN might indicate that other factors, such as light availability, limit phytoplankton growth. In those cases, initial reductions of N loading to reduce NO_x might be necessary before the effects of N control can be observed.

4.5 Deriving State-Specified Criteria

Criteria derived from the recommended national models vary with differences in lake characteristics (e.g., depth and ecoregion), and specifying a single set of criteria applicable to all lakes in a state might not account for those variations. Methods for deriving criteria that account for natural variations among water bodies are already available, and these methods can be applied to ensure that appropriate criteria are applied to different types of lakes. First, states can classify water bodies and derive different criteria for each class of water body. The

recommended national models facilitate the classification of lakes by providing specific insights into the factors that most affect the derivation of protective numeric nutrient criteria. Furthermore, the national models can be used to compute criteria for different lakes in a state to provide information about the types of lakes for which criterion magnitudes are most similar. For example, different recommended criteria for TP and TN are associated with different Level III ecoregions; however, among the ecoregions within one state, the difference in criterion magnitudes might be small enough to specify a single set of criteria applicable to multiple ecoregions. Second, site-specific criteria can be specified for a small number of lakes with characteristics that differ substantially from the rest of the lakes in a state. Here, too, the recommended national models provide the means of deriving these criteria for individual lakes.

5 References

Arend, K. K., D. Beletsky, J. V. DePinto, S. A. Ludsin, J. J. Roberts, D. K. Rucinski, D. Scavia, D. J. Schwab, and T. O. Höök. 2011. Seasonal and interannual effects of hypoxia on fish habitat quality in central Lake Erie. Freshwater Biology 56:366–383.

Bachmann, R. W., M. V. Hoyer, and D. E. C. Jr. 2003. Predicting the frequencies of high chlorophyll levels in Florida lakes from average chlorophyll or nutrient data. Lake and Reservoir Management 19:229–241.

Baird, O. E., and C. C. Krueger. 2003. Behavioral thermoregulation of brook and rainbow trout: Comparison of summer habitat use in an Adirondack River, New York. Transactions of the American Fisheries Society 132:1194–1206.

Barnett, V., and A. O'Hagan. 1997. Setting Environmental Standards: The Statistical Approach to Handling Uncertainty and Variation. Chapman and Hall/CRC, London, UK.

Bednarska, A., and P. Dawidowicz. 2007. Change in filter-screen morphology and depth selection: Uncoupled responses of Daphnia to the presence of filamentous cyanobacteria. Limnology and Oceanography 52:2358–2363.

Benndorf, Jü., W. Böing, J. Koop, and I. Neubauer. 2002. Top-down control of phytoplankton: the role of time scale, lake depth and trophic state. Freshwater Biology 47:2282–2295.

Berman, T., and D. A. Bronk. 2003. Dissolved organic nitrogen: a dynamic participant in aquatic ecosystems. Aquatic Microbial Ecology 31:279–305.

Burns, N. M. 1995. Using hypolimnetic dissolved oxygen depletion rates for monitoring lakes. New Zealand Journal of Marine and Freshwater Research 29:1–11.

Cahill, K. L., J. M. Gunn, and M. N. Futter. 2005. Modelling ice cover, timing of spring stratification, and end-of-season mixing depth in small Precambrian Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences 62:2134–2142.

Carey, C. C., B. W. Ibelings, E. P. Hoffmann, D. P. Hamilton, and J. D. Brookes. 2012. Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate. Water Research 46:1394–1407.

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361–369.

Carvalho, L., C. A. Miller (nee Ferguson), E. M. Scott, G. A. Codd, P. S. Davies, and A. N. Tyler. 2011. Cyanobacterial blooms: Statistical models describing risk factors for national-scale lake assessment and lake management. Science of The Total Environment 409:5353–5358.

Cheung, M. Y., S. Liang, and J. Lee. 2013. Toxin-producing cyanobacteria in freshwater: A review of the problems, impact on drinking water safety, and efforts for protecting public health. Journal of Microbiology 51:1–10.

Chorus, I. 2001. Cyanotoxins: occurrence, causes, consequences. Springer, Berlin, Germany.

Chow, C. W. K., M. Drikas, J. House, M. D. Burch, and R. M. A. Velzeboer. 1999. The impact of conventional water treatment processes on cells of the cyanobacterium Microcystis aeruginosa. Water Research 33:3253–3262.

Coker, G. A., C. B. Portt, and C. K. Minns. 2001. Morphological and ecological characteristics of Canadian freshwater fishes. Fisheries and Oceans Canada Burlington, Ontario.

Colby, P. J., G. R. Spangler, D. A. Hurley, and A. M. McCombie. 1972. Effects of eutrophication on salmonid communities in oligotrophic lakes. Journal of the Fisheries Research Board of Canada 29:975–983.

Cole, J. J., S. R. Carpenter, J. Kitchell, M. L. Pace, C. T. Solomon, and B. Weidel. 2011. Strong evidence for terrestrial support of zooplankton in small lakes based on stable isotopes of carbon, nitrogen, and hydrogen. Proceedings of the National Academy of Sciences 108:1975–1980.

Cornett, R. J. 1989. Predicting changes in hypolimnetic oxygen concentrations with phosphorus retention, temperature, and morphometry. Limnology and Oceanography 34:1359–1366.

Cornett, R. J., and F. H. Rigler. 1980. The areal hypolimnetic oxygen deficit: An empirical test of the model: Areal hypolimnetic oxygen deficit. Limnology and Oceanography 25:672–679.

Cornett, R. J., and F. H. Rigler. 1984. Dependence of hypolimnetic oxygen consumption on ambient oxygen concentration: Fact or artifact? Water Resources Research 20:823–830.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: A speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114:31–61.

Coutant, C. C., and D. S. Carroll. 1980. Temperatures occupied by ten ultrasonic-tagged striped bass in freshwater lakes. Transactions of the American Fisheries Society 109:195–202.

Daly, C., M. Halbleib, J. I. Smith, W. P. Gibson, M. K. Doggett, G. H. Taylor, J. Curtis, and P. P. Pasteris. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology 28:2031–2064.

De Robertis, A., C. H. Ryer, A. Veloza, and R. D. Brodeur. 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60:1517–1526.

Deevey, E. S. 1940. Limnological studies in Connecticut; Part V, A contribution of regional limnology. American Journal of Science 238:717–741.

Demers, E., and J. Kalff. 1993. A simple model for predicting the date of spring stratification in temperate and subtropical lakes. Limnology and Oceanography 38:1077–1081.

Demott, W., and D. Müller-Navarra. 1997. The importance of highly unsaturated fatty acids in zooplankton nutrition: evidence from experiments with Daphnia, a cyanobacterium and lipid emulsions. Freshwater Biology 38:649–664.

Diaz, R. J. 2001. Overview of hypoxia around the world. Journal of Environmental Quality 30:275–281.

Dillon, P. J., and F. H. Rigler. 1974. The phosphorus-chlorophyll relationship in lakes. Limnology and Oceanography 19:767–773.

Dokulil, M. T., and K. Teubner. 2000. Cyanobacterial dominance in lakes. Hydrobiologia 438:1–12.

Dolman, A. M., J. Rücker, F. R. Pick, J. Fastner, T. Rohrlack, U. Mischke, and C. Wiedner. 2012. Cyanobacteria and cyanotoxins: The influence of nitrogen versus phosphorus. PLoS ONE 7:e38757.

Downing, J. A., S. B. Watson, and E. McCauley. 2001. Predicting cyanobacteria dominance in lakes. Canadian Journal of Fisheries and Aquatic Sciences 58:1905–1908.

Duane, S., A. D. Kennedy, B. J. Pendleton, and D. Roweth. 1987. Hybrid monte carlo. Physics Letters B 195:216–222.

Dumont, H. J., I. V. de Velde, and S. Dumont. 1975. The dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from the plankton, periphyton and benthos of continental waters. Oecologia 19:75–97.

Eaton, J. G., and R. M. Scheller. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. Limnology and Oceanography 41:1109–1115.

Effler, S. W., and S. M. O'Donnell. 2010. A long-term record of epilimnetic phosphorus patterns in recovering Onondaga Lake, New York. Fundamental and Applied Limnology / Archiv für Hydrobiologie 177:1–18.

Elser, J. J. 1999. The pathway to noxious cyanobacteria blooms in lakes: the food web as the final turn. Freshwater Biology 42:537–543.

Elton, C. S. 1927. Animal Ecology. University of Chicago Press.

Evans, D. O., K. H. Nicholls, Y. C. Allen, and M. J. McMurtry. 1996. Historical land use, phosphorus loading, and loss of fish habitat in Lake Simcoe, Canada. Canadian Journal of Fisheries and Aquatic Sciences 53:194–218.

Ferber, L. R., S. N. Levine, A. Lini, and G. P. Livingston. 2004. Do cyanobacteria dominate in eutrophic lakes because they fix atmospheric nitrogen? Freshwater Biology 49:690–708.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. Journal of the Fisheries Research Board of Canada 15:607–624.

Filstrup, C. T., H. Hillebrand, A. J. Heathcote, W. S. Harpole, and J. A. Downing. 2014a. Cyanobacteria dominance influences resource use efficiency and community turnover in phytoplankton and zooplankton communities. Ecology Letters 17:464–474.

Filstrup, C. T., T. Wagner, P. A. Soranno, E. H. Stanley, C. A. Stow, K. E. Webster, and J. A. Downing. 2014b. Regional variability among nonlinear chlorophyll—phosphorus relationships in lakes. Limnology and Oceanography 59:1691–1703.

Fischer, W. J., I. Garthwaite, C. O. Miles, K. M. Ross, J. B. Aggen, A. R. Chamberlin, N. R. Towers, and D. R. Dietrich. 2001. Congener-independent immunoassay for microcystins and nodularins. Environmental Science & Technology 35:4849–4856.

Galapate, R. P., A. U. Baes, and M. Okada. 2001. Transformation of dissolved organic matter during ozonation: Effects on trihalomethane formation potential. Water Research 35:2201–2206.

Gelman, A. 2006. Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). Bayesian Analysis 1:515–534.

Gelman, A., and J. Hill. 2007. Data analysis using regression and multilevel/hierarchical models. Cambridge University Press, New York, NY.

del Giorgio, P. A., and J. M. Gasol. 1995. Biomass distribution in freshwater plankton communities. The American Naturalist 146:135–152.

Gloss, S. P., L. M. Mayer, and D. E. Kidd. 1980. Advective control of nutrient dynamics in the epilimnion of a large reservoir. Limnology and Oceanography 25:219–228.

Godfrey, P. J. 1982. The eutrophication of Cayuga Lake: a historical analysis of the phytoplankton's response to phosphate detergents. Freshwater Biology 12:149–166.

Gorham, E., and F. M. Boyce. 1989. Influence of lake surface area and depth upon thermal stratification and the depth of the summer thermocline. Journal of Great Lakes Research 15:233–245.

Graham, J. L., K. A. Loftin, M. T. Meyer, and A. C. Ziegler. 2010. Cyanotoxin mixtures and taste-and-odor compounds in cyanobacterial blooms from the midwestern United States. Environ. Sci. Technol. 44:7361–7368.

Graham, N. J. D., V. E. Wardlaw, R. Perry, and J.-Q. Jiang. 1998. The significance of algae as trihalomethane precursors. Water Science and Technology 37:83–89.

Hamilton, D. P., and S. F. Mitchell. 1996. An empirical model for sediment resuspension in shallow lakes. Hydrobiologia 317:209–220.

Haney, J. F. 1987. Field studies on zooplankton-cyanobacteria interactions. New Zealand Journal of Marine and Freshwater Research 21:467–475.

Hanson, P. C., D. L. Bade, S. R. Carpenter, and T. K. Kratz. 2003. Lake metabolism: Relationships with dissolved organic carbon and phosphorus. Limnology and Oceanography 48:1112–1119.

Havens, K. E., and G. K. Nürnberg. 2004. The phosphorus-chlorophyll relationship in lakes: Potential influences of color and mixing regime. Lake and Reservoir Management 20:188–196.

Heathcote, A. J., C. T. Filstrup, D. Kendall, and J. A. Downing. 2016. Biomass pyramids in lake plankton: influence of Cyanobacteria size and abundance. Inland Waters 6:250–257.

Heiskary, S., and B. Wilson. 2008. Minnesota's approach to lake nutrient criteria development. Lake and Reservoir Management 24:282–297.

Hessen, D. O. 2008. Efficiency, energy and stoichiometry in pelagic food webs; Reciprocal roles of food quality and food quantity. Freshwater Reviews 1:43–57.

Hessen, D. O., B. A. Faafeng, P. Brettum, and T. Andersen. 2006. Nutrient enrichment and planktonic biomass ratios in lakes. Ecosystems 9:516–527.

Hoeger, S. J., B. C. Hitzfeld, and D. R. Dietrich. 2005. Occurrence and elimination of cyanobacterial toxins in drinking water treatment plants. Toxicology and Applied Pharmacology 203:231–242.

Holmes, R., R. Norris, T. Smayda, and E. J. F. Wood. 1969. Collection, fixation, identification, and enumeration of phytoplankton standing stock. Recommended procedures for measuring the productivity of plankton standing stock and related oceanic properties. Washington (DC): National Academy of Sciences:17–46.

Hondzo, M., and H. G. Stefan. 1993. Lake water temperature simulation model. Journal of Hydraulic Engineering 119:1251–1273.

Hoyer, M. V., and J. R. Jones. 1983. Factors affecting the relation between phosphorus and chlorophyll a in Midwestern reservoirs. Canadian Journal of Fisheries and Aquatic Sciences 40:192–199.

Hutchinson, G. E. 1938. On the relation between the oxygen deficit and the productivity and typology of lakes. Internationale Revue der gesamten Hydrobiologie und Hydrographie 36:336–355.

Jacobson, P. C., T. S. Jones, P. Rivers, and D. L. Pereira. 2008. Field Estimation of a Lethal Oxythermal Niche Boundary for Adult Ciscoes in Minnesota Lakes. Transactions of the American Fisheries Society 137:1464–1474.

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.

Jacquet, S., J.-F. Briand, C. Leboulanger, C. Avois-Jacquet, L. Oberhaus, B. Tassin, B. Vinçon-Leite, G. Paolini, J.-C. Druart, O. Anneville, and J.-F. Humbert. 2005. The proliferation of the toxic cyanobacterium Planktothrix rubescens following restoration of the largest natural French lake (Lac du Bourget). Harmful Algae 4:651–672.

Jenny, J.-P., P. Francus, A. Normandeau, F. Lapointe, M.-E. Perga, A. Ojala, A. Schimmelmann, and B. Zolitschka. 2016. Global spread of hypoxia in freshwater ecosystems during the last three centuries is caused by rising local human pressure. Global Change Biology 22:1481–1489.

Jeppesen, E., J. P. Jensen, C. Jensen, B. Faafeng, D. O. Hessen, M. Søndergaard, T. Lauridsen, P. Brettum, and K. Christoffersen. 2003. The impact of nutrient state and lake depth on top-down control in the pelagic zone of lakes: A study of 466 lakes from the temperate zone to the arctic. Ecosystems 6:313–325.

Jones, F. E., and G. L. Harris. 1992. ITS-90 density of water formulation for volumetric standards calibration. Journal of research of the National Institute of Standards and Technology 97:335–340.

Jones, J. R., and R. W. Bachmann. 1976. Prediction of phosphorus and chlorophyll Levels in lakes. Journal (Water Pollution Control Federation) 48:2176–2182.

Jones, J. R., and M. F. Knowlton. 2005. Chlorophyll response to nutrients and non-algal seston in Missouri reservoirs and oxbow lakes. Lake and Reservoir Management 21:361–371.

Jones, J. R., M. F. Knowlton, D. V. Obrecht, and J. L. Graham. 2011. Temperature and oxygen in Missouri reservoirs. Lake and Reservoir Management 27:173–182.

Jones, J. R., D. V. Obrecht, B. D. Perkins, M. F. Knowlton, A. P. Thorpe, S. Watanabe, and R. R. Bacon. 2008. Nutrients, seston, and transparency of Missouri reservoirs and oxbow lakes: An analysis of regional limnology. Lake and Reservoir Management 24:155–180.

Kasprzak, P., J. Padisák, R. Koschel, L. Krienitz, and F. Gervais. 2008. Chlorophyll a concentration across a trophic gradient of lakes: An estimator of phytoplankton biomass? Limnologica - Ecology and Management of Inland Waters 38:327–338.

Keeler, B. L., S. A. Wood, S. Polasky, C. Kling, C. T. Filstrup, and J. A. Downing. 2015. Recreational demand for clean water: evidence from geotagged photographs by visitors to lakes. Frontiers in Ecology and the Environment 13:76–81.

Klumb, R. A., K. L. Bunch, E. L. Mills, L. G. Rudstam, G. Brown, C. Knauf, R. Burton, and F. Arrhenius. 2004. Establishment of a metalimnetic oxygen refuge for zooplankton in a productive lake ontario embayment. Ecological Applications 14:113–131.

Knowlton, M. F., M. V. Hoyer, and J. R. Jones. 1984. Sources of variability in phosphorus and chlorophyll and their effects on use of lake survey data. Journal of the American Water Resources Association 20:397–408.

Knowlton, M. F., and J. R. Jones. 2000. Non-algal seston, light, nutrients and chlorophyll in Missouri reservoirs. Lake and Reservoir Management 16:322–332.

Kritzberg, E. S., J. J. Cole, M. L. Pace, W. Granéli, and D. L. Bade. 2004. Autochthonous versus allochthonous carbon sources of bacteria: Results from whole-lake 13C addition experiments. Limnology and Oceanography 49:588–596.

Lawrence, S. G., D. F. Malley, W. J. Findlay, M. A. Maclver, and I. L. Delbaere. 1987. Method for estimating dry weight of freshwater planktonic crustaceans from measures of length and shape. Canadian Journal of Fisheries and Aquatic Sciences 44:s264–s274.

Lee, W. C., and E. P. Bergersen. 1996. Influence of thermal and oxygen stratification on lake trout hooking mortality. North American Journal of Fisheries Management 16:175–181.

Leibold, M. A., J. M. Chase, J. B. Shurin, and A. L. Downing. 1997. Species turnover and the regulation of trophic structure. Annual Review of Ecology and Systematics 28:467–494.

Lewis, W. M. 1983. A revised classification of lakes based on mixing. Canadian Journal of Fisheries and Aquatic Sciences 40:1779–1787.

Lewis, W. M., and W. A. Wurtsbaugh. 2008. Control of lacustrine phytoplankton by nutrients: Erosion of the phosphorus paradigm. International Review of Hydrobiology 93:446–465.

Lienesch, P. W., M. E. McDonald, A. E. Hershey, W. J. O'Brien, and N. D. Bettez. 2005. Effects of a whole-lake, experimental fertilization on lake trout in a small oligotrophic arctic lake. Hydrobiologia 548:51–66.

Loftin, K. A., M. Meyer, F. Rubio, L. Kamp, E. Humphries, and E. Whereat. 2008. Comparison of two cell lysis procedures for recovery of microcystins in water samples from Silver Lake in Dover, Delaware, with microcystin producing cyanobacterial accumulations. Open-File Report, United States Geological Survey, Reston, VA.

Mackenzie-Grieve, J. L., and J. R. Post. 2006. Thermal habitat use by lake trout in two contrasting Yukon Territory lakes. Transactions of the American Fisheries Society 135:727–738.

Marcus, M. D., W. A. Hubert, and S. H. Anderson. 1984. Habitat Suitability Index Models: Lake Trout (Exclusive of the Great Lakes). U.S. Fish and Wildlife Service.

Mazumder, A. 1994. Phosphorus–chlorophyll relationships under contrasting herbivory and thermal stratification: predictions and patterns. Canadian Journal of Fisheries and Aquatic Sciences 51:390–400.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. A manual on methods for the assessment of secondary productivity in fresh waters:228–265.

McCauley, E., J. A. Downing, and S. Watson. 1989. Sigmoid relationships between nutrients and chlorophyll among lakes. Canadian Journal of Fisheries and Aquatic Sciences 46:1171–1175.

McMahon, T. E., J. W. Terrell, and P. C. Nelson. 1984. Habitat Suitability Information: Walleye. Page 43. Division of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC.

Mellina, E., J. B. Rasmussen, and E. L. Mills. 1995. Impact of zebra mussel (Dreissena polymorpha) on phosphorus cycling and chlorophyll in lakes. Canadian Journal of Fisheries and Aquatic Sciences 52:2553–2573.

Molot, L. A., and P. J. Dillon. 1991. Nitrogen/phosphorus ratios and the prediction of chlorophyll in phosphorus-limited lakes in central Ontario. Canadian Journal of Fisheries and Aquatic Sciences 48:140–145.

Molot, L. A., P. J. Dillon, B. J. Clark, and B. P. Neary. 1992. Predicting end-of-summer oxygen profiles in stratified lakes. Canadian Journal of Fisheries and Aquatic Sciences 49:2363–2372.

Müller, B., L. D. Bryant, A. Matzinger, and A. Wüest. 2012. Hypolimnetic oxygen depletion in eutrophic lakes. Environmental Science & Technology 46:9964–9971.

Müller-Navarra, D. C., M. T. Brett, A. M. Liston, and C. R. Goldman. 2000. A highly unsaturated fatty acid predicts carbon transfer between primary producers and consumers. Nature 403:74–77.

Norton, S. B., D. J. Rodier, W. H. van der Schalie, W. P. Wood, M. W. Slimak, and J. H. Gentile. 1992. A framework for ecological risk assessment at the EPA. Environmental Toxicology and Chemistry 11:1663–1672.

Olson, J. R., and C. P. Hawkins. 2013. Developing site-specific nutrient criteria from empirical models. Freshwater Science 32:719–740.

Pace, M. L., J. J. Cole, S. R. Carpenter, J. F. Kitchell, J. R. Hodgson, M. C. Van de Bogert, D. L. Bade, E. S. Kritzberg, and D. Bastviken. 2004. Whole-lake carbon-13 additions reveal terrestrial support of aquatic food webs. Nature 427:240–243.

Paerl, H. W., and T. G. Otten. 2013. Harmful cyanobacterial blooms: Causes, consequences, and controls. Microbial Ecology 65:995–1010.

Paerl, H. W., J. T. Scott, M. J. McCarthy, S. E. Newell, W. S. Gardner, K. E. Havens, D. K. Hoffman, S. W. Wilhelm, and W. A. Wurtsbaugh. 2016. It takes two to tango: When and where dual nutrient (N & P) reductions are needed to protect lakes and downstream ecosystems. Environmental Science & Technology 50:10805–10813.

Paerl, H. W., and J. F. Ustach. 1982. Blue-green algal scums: An explanation for their occurrence during freshwater blooms. Limnology and Oceanography 27:212–217.

Park, S., M. T. Brett, E. T. Oshel, and C. R. Goldman. 2003. Seston food quality and Daphnia production efficiencies in an oligo-mesotrophic Subalpine Lake. Aquatic Ecology 37:123–136.

Perkins, R. G., and G. J. C. Underwood. 2000. Gradients of chlorophyll a and water chemistry along an eutrophic reservoir with determination of the limiting nutrient by in situ nutrient addition. Water Research 34:713–724.

Persson, J., M. T. Brett, T. Vrede, and J. L. Ravet. 2007. Food quantity and quality regulation of trophic transfer between primary producers and a keystone grazer (Daphnia) in pelagic freshwater food webs. Oikos 116:1152–1163.

Phillips, G., O.-P. Pietiläinen, L. Carvalho, A. Solimini, A. Lyche Solheim, and A. Cardoso. 2008. Chlorophyll–nutrient relationships of different lake types using a large European dataset. Aquatic Ecology 42:213–226.

Phillips, G., N. Willby, and B. Moss. 2016. Submerged macrophyte decline in shallow lakes: What have we learnt in the last forty years? Aquatic Botany.

Pilotto, L. S., R. M. Douglas, M. D. Burch, S. Cameron, M. Beers, G. J. Rouch, P. Robinson, M. Kirk, C. T. Cowie, S. Hardiman, C. Moore, and R. G. Attewell. 1997. Health effects of exposure to cyanobacteria (blue–green algae) during recreational water–related activities. Australian and New Zealand Journal of Public Health 21:562–566.

Plumb, J. M., and P. J. Blanchfield. 2009. Performance of temperature and dissolved oxygen criteria to predict habitat use by lake trout (Salvelinus namaycush). Canadian Journal of Fisheries and Aquatic Sciences 66:2011–2023.

Pollard, A. I., S. E. Hampton, and D. M. Leech. 2018. The promise and potential of continental-scale limnology using the U.S. Environmental Protection Agency's National Lakes Assessment. Limnology and Oceanography Bulletin 27:36–41.

Prairie, Y. T., C. M. Duarte, and J. Kalff. 1989. Unifying nutrient—chlorophyll relationships in lakes. Canadian Journal of Fisheries and Aquatic Sciences 46:1176–1182.

Prepas, E. E., and D. O. Trew. 1983. Evaluation of the phosphorus–chlorophyll relationship for lakes of the Precambrian Shield in western Canada. Canadian Journal of Fisheries and Aquatic Sciences 40:27–35.

Pridmore, R. D., W. N. Vant, and J. C. Rutherford. 1985. Chlorophyll-nutrient relationships in North Island lakes (New Zealand). Hydrobiologia 121:181–189.

Qian, S. S., and R. J. Miltner. 2015. A continuous variable Bayesian networks model for water quality modeling: A case study of setting nitrogen criterion for small rivers and streams in Ohio, USA. Environmental Modelling & Software 69:14–22.

Quinlan, R., A. M. Paterson, J. P. Smol, M. S. V. Douglas, and B. J. Clark. 2005. Comparing different methods of calculating volume-weighted hypolimnetic oxygen (VWHO) in lakes. Aquatic Sciences 67:97–103.

Quirós, R. 1990. Factors related to variance of residuals in chlorophyll — total phosphorus regressions in lakes and reservoirs of Argentina. Hydrobiologia 200–201:343–355.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reynolds, C. S., and S. C. Maberly. 2002. A simple method for approximating the supportive capacities and metabolic constraints in lakes and reservoirs. Freshwater Biology 47:1183–1188.

Rognerud, S., and G. Kjellberg. 1984. Relationships between phytoplankton and zooplankton biomass in large lakes. SIL Proceedings, 1922-2010 22:666–671.

Sakamoto, M. 1966. Primary production by phytoplankton community in some Japanese lakes and its dependence on lake depth. Archiv fur Hydrobiologie 62:1–28.

Sartory, D. P., and J. U. Grobbelaar. 1984. Extraction of chlorophyll a from freshwater phytoplankton for spectrophotometric analysis. Hydrobiologia 114:177–187.

Scavia, D., J. David Allan, K. K. Arend, S. Bartell, D. Beletsky, N. S. Bosch, S. B. Brandt, R. D. Briland, I. Daloğlu, J. V. DePinto, D. M. Dolan, M. A. Evans, T. M. Farmer, D. Goto, H. Han, T. O. Höök, R. Knight, S. A. Ludsin, D. Mason, A. M. Michalak, R. Peter Richards, J. J. Roberts, D. K. Rucinski, E. Rutherford, D. J. Schwab, T. M. Sesterhenn, H. Zhang, and Y. Zhou. 2014. Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia. Journal of Great Lakes Research 40:226–246.

Scheffer, M., and E. H. van Nes. 2007. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. Hydrobiologia 584:455–466.

Scheffer, M., S. Rinaldi, A. Gragnani, L. R. Mur, and E. H. van Nes. 1997. On the dominance of filamentous cyanobacteria in shallow, turbid lakes. Ecology 78:272–282.

Schindler, D. W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment. Proceedings of the National Academy of Sciences 105:11254–11258.

Schindler, D. W., M. A. Turner, and R. H. Hesslein. 1985. Acidification and alkalinization of lakes by experimental addition of nitrogen compounds. Biogeochemistry 1:117–133.

Smeltzer, E., and S. A. Heiskary. 1990. Analysis and applications of lake user survey data. Lake and Reservoir Management 6:109–118.

Smith, V. H. 1982. The nitrogen and phosphorus dependence of algal biomass in lakes: an empirical and theoretical analysis. Limnology and Oceanography 27:1101–1112.

Smith, V. H., S. B. Joye, and R. W. Howarth. 2006. Eutrophication of freshwater and marine ecosystems. Limnology and Oceanography 51:351–355.

Smith, V. H., and D. W. Schindler. 2009. Eutrophication science: where do we go from here? Trends in Ecology & Evolution 24:201–207.

Snucins, E. J., and J. M. Gunn. 1995. Coping with a warm environment: Behavioral thermoregulation by lake trout. Transactions of the American Fisheries Society 124:118–123.

Søndergaard, M., J. P. Jensen, and E. Jeppesen. 2005. Seasonal response of nutrients to reduced phosphorus loading in 12 Danish lakes. Freshwater Biology 50:1605–1615.

Spears, B. M., L. Carvalho, B. Dudley, and L. May. 2013. Variation in chlorophyll a to total phosphorus ratio across 94 UK and Irish lakes: Implications for lake management. Journal of Environmental Management 115:287–294.

Stan Development Team. 2016. Stan Modeling Language Users Guide and Reference Manual, Version 2.14.0.

Stefan, H. G., X. Fang, D. Wright, J. G. Eaton, and J. H. McCormick. 1995. Simulation of dissolved oxygen profiles in a transparent, dimictic lake. Limnology and Oceanography 40:105–118.

Stefan, H. G., M. Hondzo, X. Fang, J. G. Eaton, and J. H. McCormick. 1996. Simulated long-term temperature and dissolved oxygen characteristics of lakes in the north-central United States and associated fish habitat limits. Limnology and Oceanography 41:1124–1135.

Stemberger, R. S. 1995. The influence of mixing on rotifer assemblages of Michigan lakes. Hydrobiologia 297:149–161.

Stewart, I., A. A. Seawright, and G. R. Shaw. 2008. Cyanobacterial poisoning in livestock, wild mammals and birds – an overview. Pages 613–637 *in* H. K. Hudnell, editor. Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs. Springer New York.

Tessier, A. J., and J. Welser. 1991. Cladoceran assemblages, seasonal succession and the importance of a hypolimnetic refuge. Freshwater Biology 25:85–93.

US EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum, Washington, DC.

US EPA. 2000a. Nutrient Criteria Technical Guidance Manual, Lakes and Reservoirs. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 2000b. Nutrient Criteria Technical Guidance Manual, Rivers and Streams. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 2001. Nutrient Criteria Technical Guidance Manual, Estuarine and Coastal Marine Waters. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 2007. Survey of the Nation's Lakes: Field Operations Manual. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2008. Nutrient Criteria Technical Guidance Manual, Wetlands. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 2009. Survey of the Nation's Lakes: Quality Assurance Project Plan. Office of Water and Office of Environmental Information, Washington, DC.

US EPA. 2010a. Using stressor-response relationships to derive numeric nutrient criteria. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2010b. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. Office of Water and Office of Research and Development, Washington, DC.

US EPA. 2011. 2012 National Lakes Assessment. Field Operations Manual. Office of Water, US Environmental Protection Agency, Washington, DC.

US EPA. 2012a. 2012 National Lakes Assessment. Laboratory Operations Manual. U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2012b. 2012 National Lakes Assessment Quality Assurance Project Plan. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2012c. 2012 National Lakes Assessment Site Evaluation Guidelines. Office of Water, Washington, DC.

US EPA. 2014. Framework for Human Health Risk Assessment to Inform Decision Making. Risk Assessment Forum, Washingon, DC.

US EPA. 2015a. Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria. Office of Water, Washington DC.

US EPA. 2015b. Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2015c. Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

US EPA. 2019. Recommended human health recreational ambient water quality criteria or swimming advisories for microcystins and cylindrospermopsin. Office of Water, Washington DC.

Vadeboncoeur, Y., E. Jeppesen, M. J. V. Zanden, H.-H. Schierup, K. Christoffersen, and D. M. Lodge. 2003. From Greenland to green lakes: Cultural eutrophication and the loss of benthic pathways in lakes. Limnology and Oceanography 48:1408–1418.

Vanderploeg, H. A., S. A. Ludsin, S. A. Ruberg, T. O. Höök, S. A. Pothoven, S. B. Brandt, G. A. Lang, J. R. Liebig, and J. F. Cavaletto. 2009. Hypoxia affects spatial distributions and overlap of pelagic fish, zooplankton, and phytoplankton in Lake Erie. Journal of Experimental Marine Biology and Ecology 381, Supplement:S92–S107.

Vanni, M. J. 1987. Effects of nutrients and zooplankton size on the structure of a phytoplankton community. Ecology 68:624–635.

Wagner, T., P. A. Soranno, K. E. Webster, and K. S. Cheruvelil. 2011. Landscape drivers of regional variation in the relationship between total phosphorus and chlorophyll in lakes. Freshwater Biology 56:1811–1824.

Walker, W. W. 1979. Use of hypolimnetic oxygen depletion rate as a trophic state index for lakes. Water Resources Research 15:1463–1470.

Westrick, J. A., D. C. Szlag, B. J. Southwell, and J. Sinclair. 2010. A review of cyanobacteria and cyanotoxins removal/inactivation in drinking water treatment. Analytical and Bioanalytical Chemistry 397:1705–1714.

Wetzel, R. G. 2001. Limnology, Third Edition: Lake and River Ecosystems. Academic Press, San Diego.

Wood, S. N. 2006. Generalized additive models: An introduction with R. CRC Press, Boca Raton, FL.

Yuan, L. L., and J. R. Jones. 2019. A Bayesian network model for estimating stoichiometric ratios of lake seston components. Inland Waters 9:61–72.

Yuan, L. L., and J. R. Jones. 2020a. Modeling hypolimnetic dissolved oxygen depletion using monitoring data. Canadian Journal of Fisheries and Aquatic Sciences 77:814–823.

Yuan, L. L., and J. R. Jones. 2020b. Rethinking phosphorus-chlorophyll relationships in lakes. Limnology and Oceanography.

Yuan, L. L., and A. I. Pollard. 2014. Classifying lakes to improve precision of nutrient–chlorophyll relationships. Freshwater Science 33:1184–1194.

Yuan, L. L., and A. I. Pollard. 2017. Using national-scale data to develop nutrient–microcystin relationships that guide management decisions. Environmental Science & Technology 51:6972–6980.

Yuan, L. L., and A. I. Pollard. 2018. Changes in the relationship between zooplankton and phytoplankton biomasses across a eutrophication gradient. Limnology and Oceanography 63:2493–2507.

Yuan, L. L., and A. I. Pollard. 2019. Combining national and state data improves predictions of microcystin concentration. Harmful Algae 84:75–83.

Zhang, F., J. Lee, S. Liang, and C. K. Shum. 2015. Cyanobacteria blooms and non-alcoholic liver disease: evidence from a county level ecological study in the United States. Environmental Health 14:41.

Appendix A: State Case Study: Chlorophyll *a*-Microcystin

This case study in Iowa describes chlorophyll *a* (Chl *a*) and microcystin data collected by the Iowa Department of Natural Resources (IDNR) that are combined with national data to estimate a stressor-response relationship for the state (Yuan and Pollard 2019).

A.1 Data

Chl *a* measurements in Iowa were collected as part of an ambient lake monitoring program conducted by IDNR. Water samples were collected with an integrated water column sampler above the thermocline, when present, to a maximum depth of 2 meters (m) at the deepest point of each lake. Lake water samples were collected in the summer (May–September). An aliquot of the water sample was analyzed for Chl *a* in the laboratory by non-acidified fluorometry after filtering water samples through GF/C filters. In a separate IDNR monitoring program, microcystin concentrations are sampled regularly at swimming beaches in Iowa during the summer. This sampling effort includes state park beaches and locally managed beaches across the state. Microcystin was quantified in composite water samples collected at nine different locations on three transects spanning the swimming beach. On each transect, samples were collected at depths of 0.15, 0.5, and 1.0 m. Chl *a* and microcystin samples were matched by lake and sampling date for use in the analysis. To maximize the available data, microcystin and Chl *a* measurements collected within 1 day of each other were included as matched samples.

A.2 Statistical Analysis

The structure of a statistical model that accommodates data collected at different spatial scales must be defined to ensure that the available data appropriately inform model estimates. Consider the case of a large national data set of approximately 1,000 samples and a state data set of approximately 50 samples. If the two data sets were pooled, the national data would dominate the state data simply because of the larger sample size, and the state data would exert a weak influence on the model. In any single state, however, only about 20 samples from the national data might be available, and we would expect the state data to dominate

estimates. Defining a hierarchical structure in the model helps ensure that each data set exerts the appropriate influence on the model results (Gelman and Hill 2007).

A second issue that arises from combining data sets is that different measurements are often collected in the different data sets. This problem is addressed in the national models by modeling a comprehensive network of relationships between different parameters to take advantage of the many different measurements available in the National Lakes Assessment (NLA) data (Qian and Miltner 2015). Then, state data sets in which only a subset of measurements were collected could still be feasibly modeled by informing specific aspects of the network.

State data from Iowa were included in the national model and inform estimates of relationships in the same network. As mentioned earlier, however, only Chl *a* and microcystin measurements were available in the Iowa state data set. To prevent over-specifying the model, EPA selected one of the relationships in the network that could be refined with data from the state. The relationship between Chl *a* and the relative biovolume of cyanobacteria relied most heavily on empirical calibration, so it was selected for refinement with state data. More specifically, the national model was revised so that model coefficients specific to each state were estimated (Equation (17)).

$$E[logit(p_{c,i})] = f_{1,k[i]} + f_{2,k[i]}chl_i + f_{3,k[i]}chl_i^2 \quad (36)$$

where different values of each of the coefficients were estimated for each state in the United States, *k*. The values of the coefficients for each state were constrained by normal distributions defined by the parameters, μ_f and σ_f. For example, the set of state-specific coefficients for f_1 were drawn from a single normal distribution as follows:

$$f_1 \sim Normal(\mu_{f_1}, \sigma_{f_1}) \quad (37)$$

Identical expressions can be written for the set of f_2 values and f_3 values. These distributions constrained the range of possible values so estimates of those parameters computed with relatively small sample sizes within individual states can "borrow" information from estimates computed from other states (Gelman and Hill 2007).

Iowa state data were included in the model by noting that the data should inform estimates of the coefficients only in the state of Iowa. That is, estimates of f_1, f_2, and f_3 from Equation (36) in Iowa are based on both the Iowa state data set and NLA data collected in Iowa. In other states,

estimates of the coefficients are based only on NLA data. The influence of Iowa state data on the national distributions of the coefficients (as characterized by μ_f and σ_f) is limited because the data affect only one element of the overall distributions of coefficients. Within the state of Iowa, however, the coefficients can be fit to maximize the predictive accuracy of the overall relationship linking Chl *a* to microcystin for both Iowa data and NLA data collected in Iowa, while remaining consistent with the range of possible values observed across all states.

One final difference in fitting the Iowa state data is that several sources of variability modeled separately in the national model (e.g., s_1 and s_2 in equations (18) and (19)) are combined into one estimate of residual variability. This combination of error terms reflects the data available from Iowa, in which no laboratory replicates or direct measurements of cyanobacterial biovolume were available. Hence, one lumped source of variability was estimated.

For comparison, a simple bivariate model was fit using only IDNR data, in which microcystin concentration was modeled as a quadratic function of Chl *a*.

A.3 Results

A total of 556 samples of Chl *a* were measured at 28 lakes in Iowa. In some lakes, microcystin concentrations were sampled at different beaches, so 686 observations of microcystin were matched to the Chl *a* measurements.

In the revised national model with state-specific relationships between Chl *a* and the relative biovolume of cyanobacteria, coefficients varied substantially among states. Because coefficient values for quadratic relationships are not easily interpreted, the predicted mean cyanobacterial-relative biovolume at a Chl *a* concentration of 20 microgram per liter (µg/L) is plotted to visualize the range of variation among states (Figure 34). For comparison, among all the national data, mean cyanobacterial-relative biovolume was 0.18 at Chl *a* concentration of 20 µg/L. Systematic changes in cyanobacterial-relative biovolume with latitude or longitude were not evident, but some regional differences were observed. For example, cyanobacterial-relative biovolume for a Chl *a* concentration of 20 µg/L in Northeast states was generally lower than elsewhere, whereas in Midwest states, it was somewhat higher.

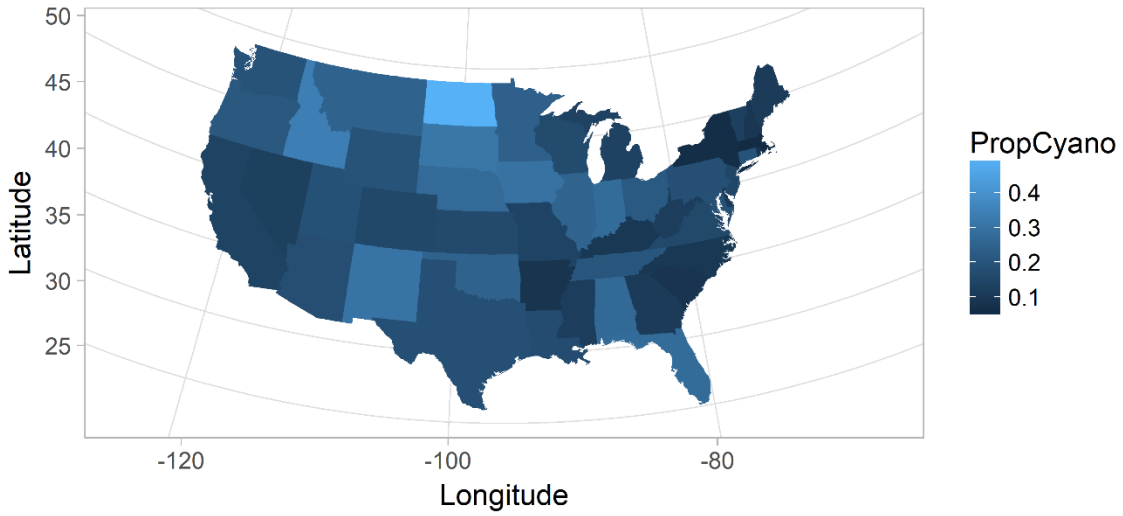

Figure 34. Variation in the relationship between Chl *a* and cyanobacterial-relative biovolume among states. PropCyano: predicted mean relative biovolume of cyanobacteria at an illustrative Chl *a* = 20 µg/L.

As described previously, the relationship between Chl *a* and cyanobacterial relative biovolume in Iowa was adjusted to maximize the accuracy of the predicted microcystin. Inclusion of Iowa data reduced the magnitude of the slope of the relationship between Chl *a* and cyanobacterial-relative biovolume but increased the intercept (Figure 35). So, higher values of cyanobacterial-relative biovolume were observed at Chl *a* concentrations less than about 10 µg/L. At higher Chl *a* concentrations, inclusion of Iowa state data did not substantively change the predicted cyanobacterial-relative biovolume. Overall, in Iowa, the estimated relationship between cyanobacterial-relative biovolume and Chl *a* was statistically indistinguishable from a constant value (Figure 35). The addition of the state data also narrowed the range of the credible intervals, as would be expected.

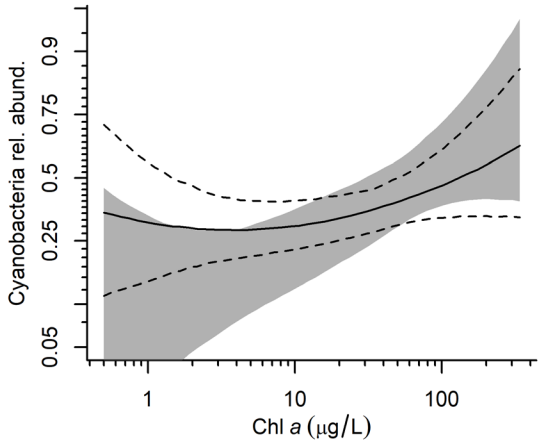

Figure 35. Comparison of Chl *a*/cyanobacterial-relative biovolume relationships in Iowa. *Filled gray*: 90% credible intervals for estimate of relationship using only NLA data collected in Iowa; *solid and dashed lines*: mean and 90% credible intervals for estimate of relationship using both Iowa state and NLA data.

The predicted mean relationship between Chl *a* and microcystin in Iowa from the state-national model closely followed the observed data (left panel, Figure 36), exhibiting a slight increase in slope as Chl *a* concentration increased. The 90% prediction intervals shown in the plot were based on the mean values of repeated random draws of 15 samples from the predicted distribution to replicate the plotted observed data. The intervals were broad and included most of the estimated mean values. The curvature observed in the simple bivariate fit between Chl *a* and microcystin using only Iowa data was opposite of that observed from the state-national model, predicting that the rate of increase in microcystin was lower at high Chl *a* concentrations than at low Chl *a* concentrations (right panel, Figure 36). The 90% prediction intervals of this fit also included most of the observed mean values, but qualitatively, the simple bivariate model did not match the observed data as closely as did the state-national model.

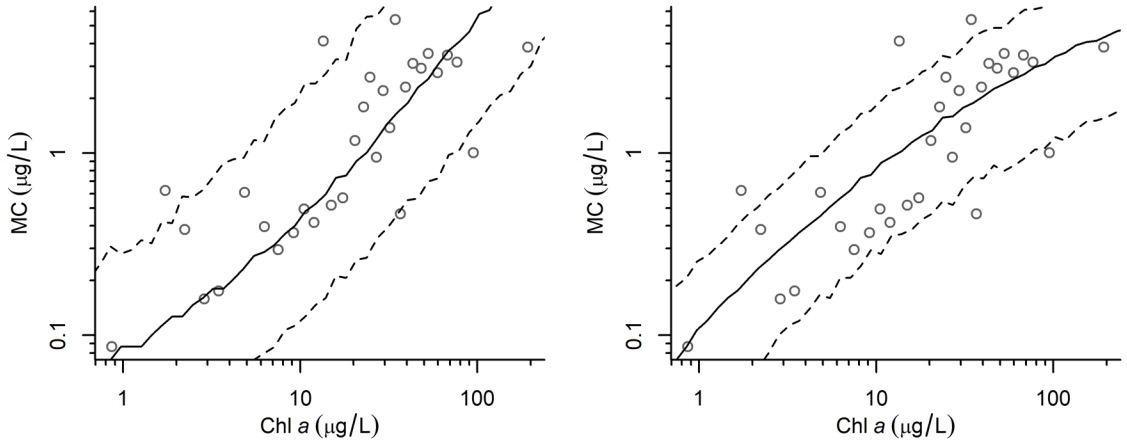

Figure 36. Comparison of predicted relationship between Chl *a* and microcystin for the state-national model (*left panel*) and a model using only Iowa state data (*right panel*). *Open circles*: average microcystin concentration computed in ~15 samples at the indicated Chl *a*; *solid lines*: mean relationship; *dashed lines*: 5th to 95th percentiles of distribution of means of 15 samples drawn from predicted distribution.

Three features inherent to the model combining state and national data are likely responsible for the improved predictions of observations in the Iowa data set. First, the network of relationships specified in the national model define a nonlinear function linking Chl *a* to microcystin that yielded a curved mean response (left panel, Figure 36). When only Iowa data are available, no information regarding the functional form of the relationship between Chl *a* and microcystin is known. Hence, it is difficult for the model to identify the correct shape of the curve. Indeed, the concavity of the mean relationship identified by the model using only Iowa data (right panel, Figure 36) was opposite of that estimated in the combined state-national model. Second, the network of relationships in the state-national model provided information regarding unobserved variables and relationships that could be used in lieu of direct observations. In this example, the relationships between Chl *a* and total phytoplankton biovolume and between cyanobacterial biovolume and microcystin were supplied by the national model. The Iowa-only model lacked the benefit of the additional information, and hence, for this model a direct relationship between Chl *a* and microcystin had to be estimated that aggregated the different causal linkages. Finally, the hierarchical structure of the national model placed constraints on the range of possible values for parameters estimated within each state. These constraints limited model parameters for the state data set to values that were generally consistent with national parameters.

A.4 Criteria Derivation

Derivation of a recommended Chl *a* criterion based on decisions such as allowable exceedance rate, targeted microcystin, and model uncertainty follows an identical process as described for the national model. The model based on both IDNR data and NLA data yields a slightly different relationship from the model estimated from only the national data (Figure 37). Slightly greater uncertainty accompanies the estimate of the mean relationship in the Iowa-NLA model than the estimate in the NLA-only model (see Figure 22), and that uncertainty is reflected in a broader range of possible Chl *a* criteria. In the example shown in Figure 37, to maintain a maximum exceedance rate of 1% of microcystin of 8 µg/L, the Chl *a* criterion associated with the bound of the 50% credible interval was 14 µg/L.

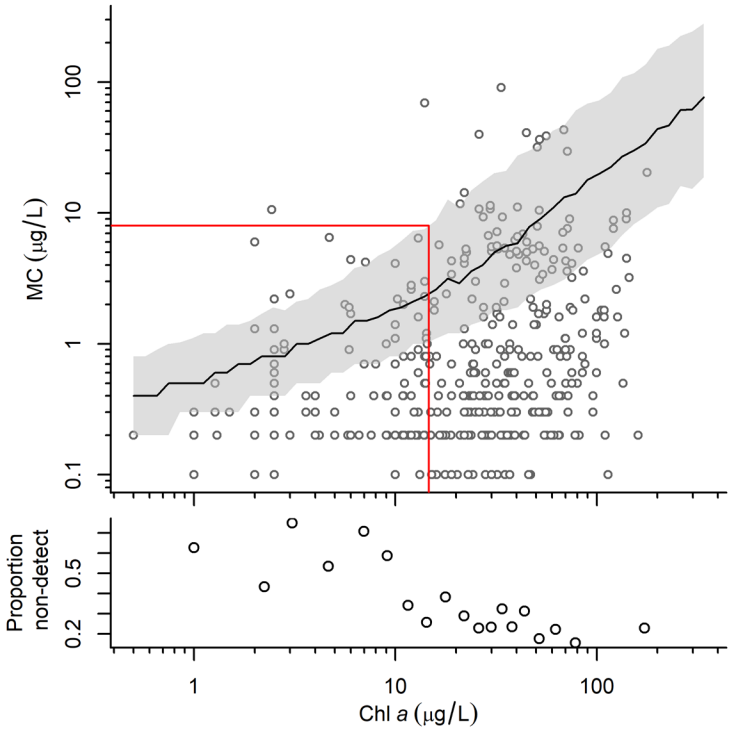

Figure 37. Microcystin and Chl *a* measurements in Iowa. *Top panel–open circles*: observed values of microcystin and Chl *a* for samples in which microcystin was greater than the detection limit; *solid line*: predicted microcystin that will be exceeded 1% of the time for the indicated Chl *a* concentration; *gray shading*: 50% credible interval about mean relationship; *horizontal and vertical line segments*: candidate Chl *a* criteria based on targeted microcystin. *Bottom panel*: proportion of samples for which microcystin was not detected in ~100 samples centered at the indicated Chl *a* concentration.

Appendix B: State Case Study: Chlorophyll *a*–Hypoxia

This case study in Missouri describes national and state data that are combined to refine estimates of the relationship between chlorophyll *a* (Chl *a*) and deep water hypoxia. As described in Section 3.2.2, mean concentrations of dissolved oxygen below the thermocline (DO_m) decrease with time during the period of summer stratification. The sampling design of the NLA allowed for one visit to most of the lakes, so estimating temporal changes in deep water DO_m in the national model required a space-for-time substitution. State monitoring data collected during multiple visits to a smaller number of lakes provided an opportunity to directly estimate temporal changes in DO_m and to compare the relationship between eutrophication and the rate of oxygen depletion with estimates from NLA data.

B.1 Data

The Missouri data considered in this case study were collected an average of 3–4 times per year by the University of Missouri (MU) from 1989 to 2007 as part of a statewide monitoring effort. Samples were collected near the dam for each reservoir (herein referred to as lakes for simplicity), where vertical profiles for temperature and DO concentration were measured (YSI model 51B or 550A meters). Composite water samples from a depth of approximately 0.25 meter (m) were transferred to high density polyethylene containers, placed in coolers on ice, and transported to the MU Limnology Laboratory. There, a 250-milliliter aliquot was filtered (Pall A/E) for determination of total Chl *a* via fluorometry following pigment extraction in heated ethanol (Knowlton et al. 1984, Sartory and Grobbelaar 1984). A total of 198 measurements of DO_m were available for analysis, collected at 20 different lakes over 62 unique lake-year combinations.

B.2 Statistical Analysis

The same model equations used in the national model were applied to data collected in Missouri:

$$E[DO_{m,i}] = DO_0 + VOD_{k[i]}\left(t_i - t_{0,j[i]}\right) \quad (38)$$

where DO_0 is the value of DO_m at the start of spring stratification, volumetric oxygen demand $(VOD)_k$ is the net imbalance in the volumetric oxygen budget for lake *k* corresponding to sample *i* expressed as milligrams per liter per day of DO (Burns 1995), t_i is the date that sample *i* is collected, and $t_{0,j}$ is the date of the beginning of stratification for lake-year *j*. Observed values of DO_m were assumed to be normally distributed with a standard deviation of σ_1 about the expected value. Note that, like the national model, VOD is assumed to be constant for each lake, but the date of the beginning of stratification varied by year and lake. The model equation specifying the relationship between Chl *a*, dissolved organic carbon (DOC), and lake depth and VOD was the same equation used in the recommended national model (see Equation (11)). As with the national model, saturation DO concentrations at the minimum temperature in Missouri were used to set the value of DO_0.

The treatment of DO measurements less than 2 milligrams per liter (mg/L) in the Missouri data differed from the approach used in the NLA. From 2 to 14 measurements of DO_m greater than 2 mg/L were available in the Missouri data set for each of the lake-years included in the model, so data were available to directly estimate temporal changes in DO_m. Because data were available at each lake before DO_m approached zero, measurements of DO_m that were less than 2 mg/L could be excluded without biasing the model results.

Two models were run to explore the effects of combining Missouri data with the national model. In the first model, only Missouri data were used, and in the second model, both Missouri and NLA data were used to estimate the parameter values.

B.3 Results

The range of values spanned by each of the covariates differed between the two data sets. Missouri measurements were collected over a broader range of days than the NLA, whereas lakes sampled by the NLA covered a broader range of Chl *a* concentrations (Figure 38). Variations in DOC concentrations and depths below the thermocline were also narrower in the Missouri data than in the NLA data. Those differences in the range of observations were reflected in the strength of correlation between each covariate and DO_m. For Missouri, sampling day was most strongly correlated with DO_m, whereas for the NLA, sampling day exhibited the weakest correlation with DO_m. Instead, in the NLA data, Chl *a*, DOC, and the depth below the thermocline were all more strongly correlated with DO_m.

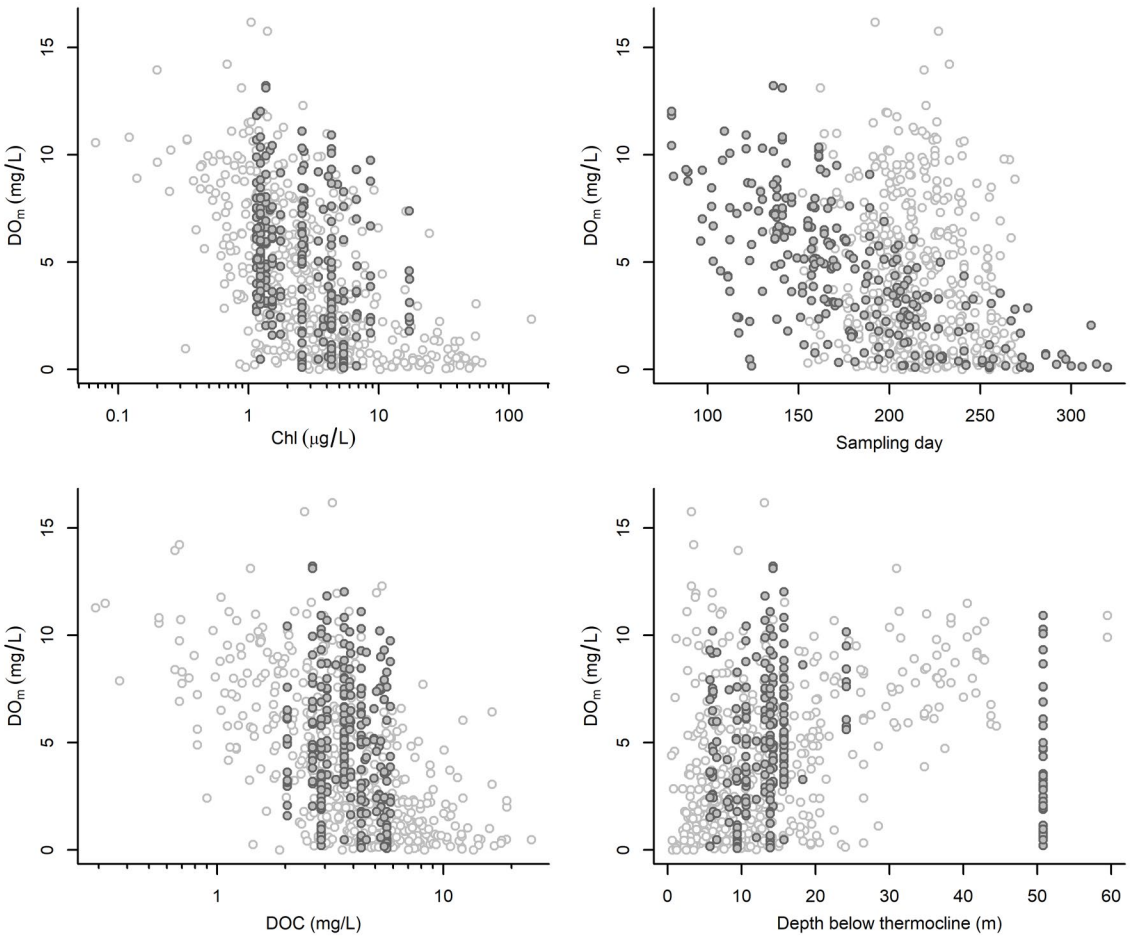

Figure 38. Observed DO_m vs. Chl *a*, sampling day, DOC, and depth below the thermocline. *Open circles*: NLA data*; filled circles*: Missouri.

The first day of stratification for Missouri lakes was generally earlier than for most of the dimictic lakes considered in the national model (Figure 39), a finding that is consistent with the fact that Missouri is located at the southern end of the geographic distribution of dimictic lakes (see Figure 7). Both the Missouri-only model and the NLA-only model yielded similar estimates of the relationship between Chl *a* and VOD (d_2 in Equation (11)) (Figure 40), and the estimate based on the combined data sets improved further on the precision. Estimates of coefficients characterizing the relationship between VOD and depth below the thermocline (d_3) and DOC (d_4) were much more precise in the NLA-only data set than in the Missouri-only data set. Hence, the estimate based on the combined data set mainly reflects the trends in the NLA data.

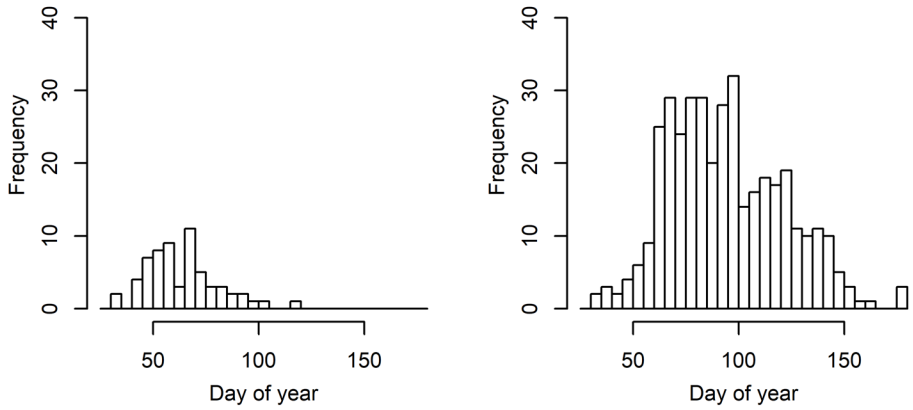

Figure 39. Estimated first day of stratification for Missouri lakes (*left panel*) and NLA lakes (*right panel*).

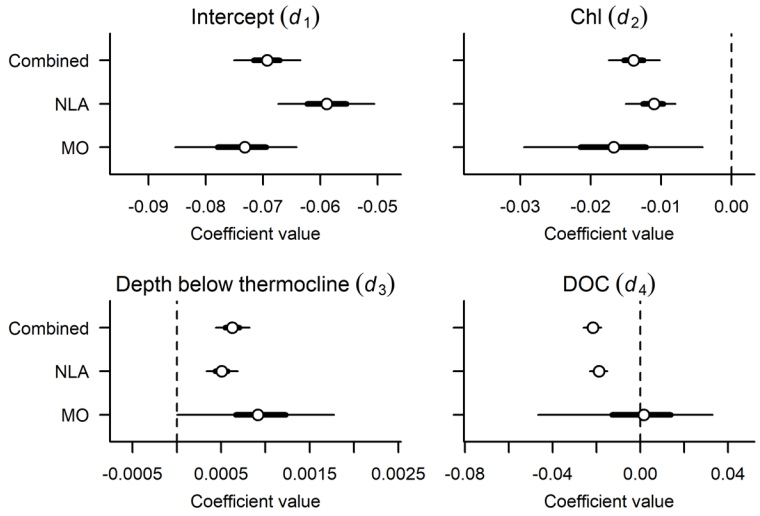

Figure 40. Model coefficients estimated for models for Missouri data, NLA data, and combined data. *Thick line segment*: 50% credible intervals; *thin line segment*: 90% credible intervals; *vertical dashed line*: coefficient value of zero.

Qualitatively, the model accurately represented the decrease in DO_m over time in different lakes (Figure 41). The effects of differences in the timing of spring stratification was manifested as differences in the vertical position of each line, and in some lakes, substantial variation was observed across years.

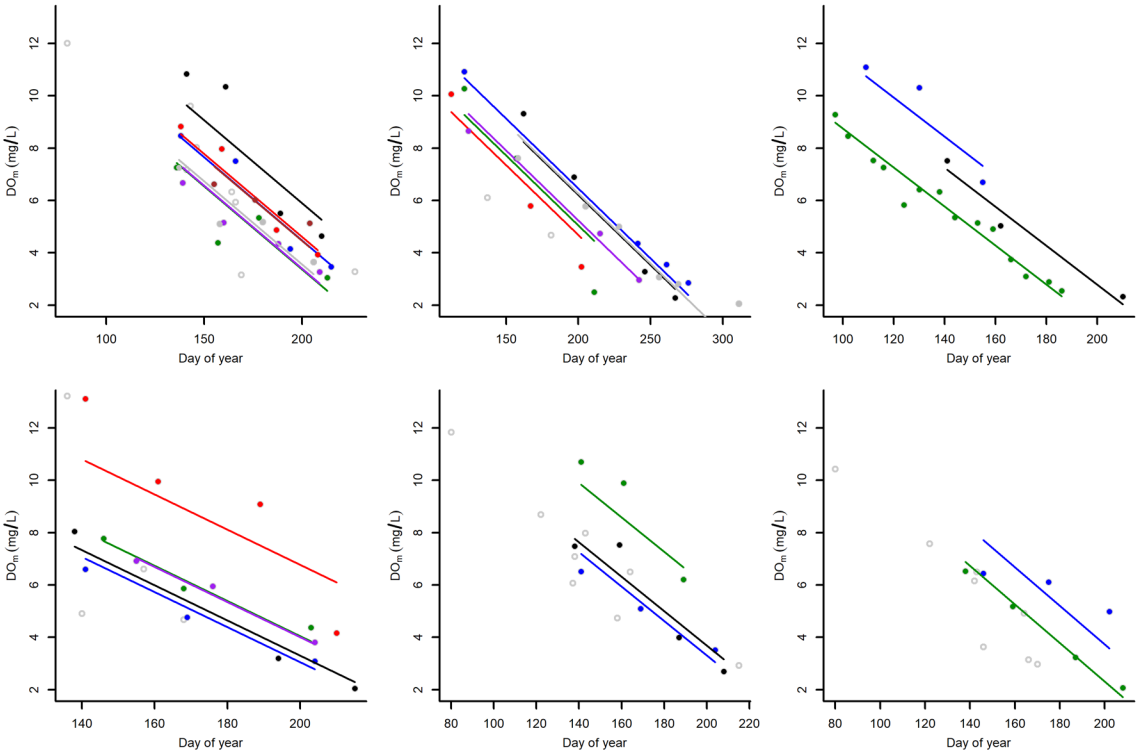

Figure 41. Relationships between day of year and DO_m for six Missouri lakes. *Different line and symbol colors in each panel* correspond to data collected within different years with at least three samples. *Open gray circles*: other samples collected at each lake.

B.4 Criteria Derivation

The utility of combining Missouri and NLA data to inform decision-making is evident when one considers the predicted relationship between Chl *a* and DO_m calculated using parameter estimates from the Missouri data and from the combined Missouri-NLA data set (Figure 42). In the example shown, the relationship is calculated based on illustrative values for other covariates (depth below thermocline at 10 m, DOC at 1.6 mg/L, and time between spring stratification and sampling at 130 days). Because use of both data sets improves the precision of model parameters, the resulting mean relationship is also estimated with increased precision and a targeted Chl *a* concentration can be identified with greater confidence. In this example, the 50% credible interval for the targeted Chl *a* concentration corresponding to an illustrative threshold of DO_m = 0.1 extends from 5.5–8.9 µg/L when the combined model is used. When using only Missouri data, the interval expands to 4.5–9.7 µg/L.

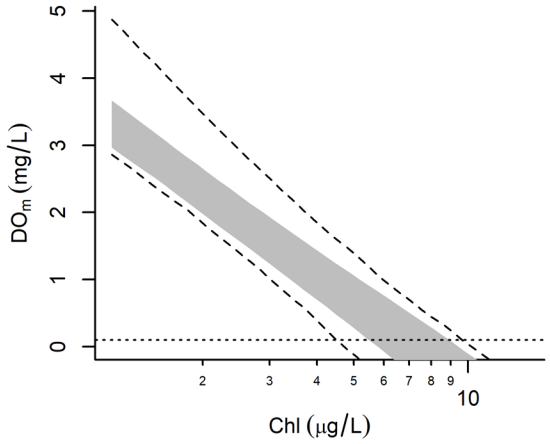

Figure 42. Relationship between Chl *a* and DO_m in an illustrative lake with depth below thermocline at 10m, DOC at 1.6 mg/L, and 130 days after spring stratification. *Gray shading*: 50% credible intervals about mean relationship from combined Missouri-NLA model; *dashed line*: 50% credible intervals about mean relationship from Missouri-only model; *dotted line*: DO_m = 0.1 mg/L.

Appendix C: State Case Study: Total Nitrogen–Chlorophyll *a*

This case study in Iowa examines how combining locally collected measurements of total nitrogen (TN) and chlorophyll *a* (Chl *a*) with the national models can refine predictions calculated from these local data sets.

C.1 Data

Data used for this case study were collected by the Iowa Department of Natural Resources (IDNR) as part of their routine monitoring program. For each lake in the data set, TN, nitrate-nitrite, Chl *a*, and dissolved organic carbon (DOC) values were measured. A total of 968 observations collected at 31 different lakes were available for analysis.

C.2 Statistical Analysis

The same model formulation provided in Equation (33) was applied to the IDNR data, expressing TN-dissolved inorganic nitrogen (-DIN) as the sum of a phytoplankton compartment, modeled as $f_1 Chl^k$, and a dissolved organic nitrogen (DON) component, modeled as $f_2 DOC$:

$$E[TN - DIN] = f_1 Chl^k + DON = f_1 Chl^k + f_2 DOC \quad (39)$$

DOC measurements were available only at a small proportion of Iowa lakes, so EPA simplified the national model to the following form for modeling Iowa data:

$$E[TN - DIN] = f_1 Chl^k + u \quad (40)$$

where u is a lake-specific constant representing the contributions of DON in each lake to observed values of TN-DIN. Recall also that, in the national model, the coefficient f_1 varied across states. With the IDNR data set, multiple samples were collected from each lake, so the model could be refined further to estimate a value of f_1 for each lake as follows:

$$\log(f_{1,j}) \sim Normal(\mu_{f1,IA}, \sigma_{f1}) \quad (41)$$

where the index, *j,* refers to different lakes, and the mean value $\mu_{f1,IA}$ is computed for data collected in Iowa.

To examine the effects of considering local state data in the context of the national model, two models were fit. In the first model, only IDNR data were used to estimate the coefficients. In the second model, relationships were fit to both the IDNR data and NLA data simultaneously. The exponent *k* was modeled as being the same in both the IDNR and NLA data, while the coefficients f_1 for each lake were estimated with IDNR data and NLA data collected within Iowa, and the value of $\mu_{f1,IA}$ was constrained by the national distribution among all the states in the NLA data.

C.3 Results

Data collected during the NLA in Iowa and by IDNR spanned similar ranges of Chl *a*, TN-DIN, and DOC (Figure 43). The limiting relationship between Chl *a* and TN-DIN estimated using only IDNR data approximated the lower edge of the cloud of points (gray shading) but were estimated with more uncertainty than when estimated using both IDNR and NLA data (solid lines). The mean limiting relationships between Chl *a* and TN-DIN estimated with the two models were statistically indistinguishable from one another.

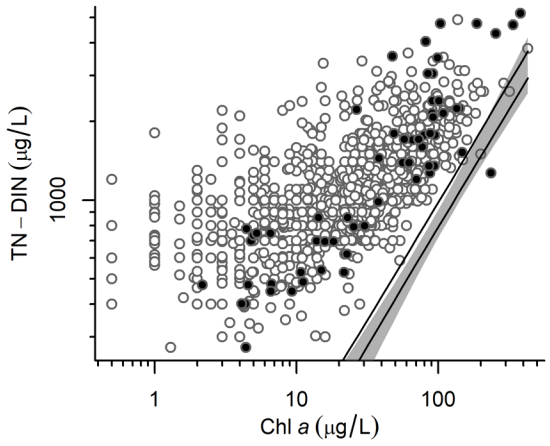

Figure 43. Chl *a* vs. TN-DIN in Iowa. *Open circles*: data collected by Iowa DNR; *filled circles*: data collected by NLA in Iowa; *solid lines*: 95% credible intervals for limiting relationships between Chl *a* and TN-DIN estimated using both NLA and IDNR data; *shaded gray area*: 95% credible intervals for limiting relationships estimated using only IDNR data.

The root mean square (RMS) prediction error of log(TN-DIN) measurements in the IDNR data was the same for the models using only IDNR data (RMS = 0.27) and the combined Iowa – NLA data (RMS = 0.27), indicating that imposing national constraints on the parameter values did not improve the accuracy of predictions at the scale of the local state data. Uncertainty about

estimates of the relationship between TN-DIN and Chl *a* for individual lakes was very similar (example shown in Figure 44), indicating that a sufficient number of samples was available for each lake to estimate the relationship without the information provided by the national model.

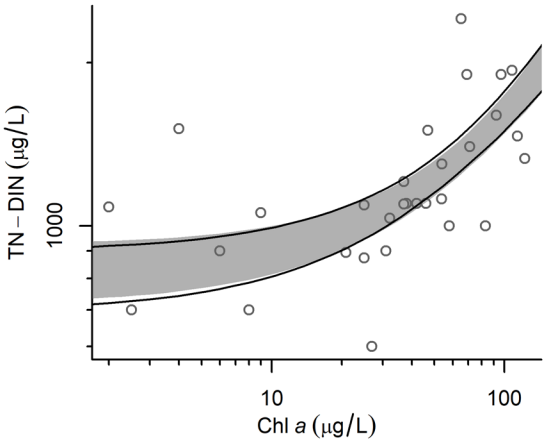

Figure 44. Chl *a* vs. TN-DIN in Beeds Lake, Iowa. *Open circles*: observed data; *gray shading*: 90% credible intervals for predicted relationship based on only IDNR data; *solid lines*: 90% credible intervals for predicted relationship using both IDNR and NLA data.

C.4 Criteria Derivation

Because of the higher number of samples collected within each lake in the IDNR data set, unique relationships between TN-DIN and Chl *a* for each lake could be calculated, and those relationships, in turn, can be used to derive numeric nutrient criteria (Figure 45). Variations across lakes in DON and in the coefficients of the modeled relationship yield differences in the estimated relationship between TN-DIN and Chl *a*. Then, resulting TN ambient criterion differ as well. For an illustrative target Chl *a* concentration of 15 micrograms per liter (µg/L), the mean ambient TN criterion for the lake shown in the left panel of Figure 45 was 750 µg/L, while the TN criterion for the lake in the right panel was 1260 µg/L.

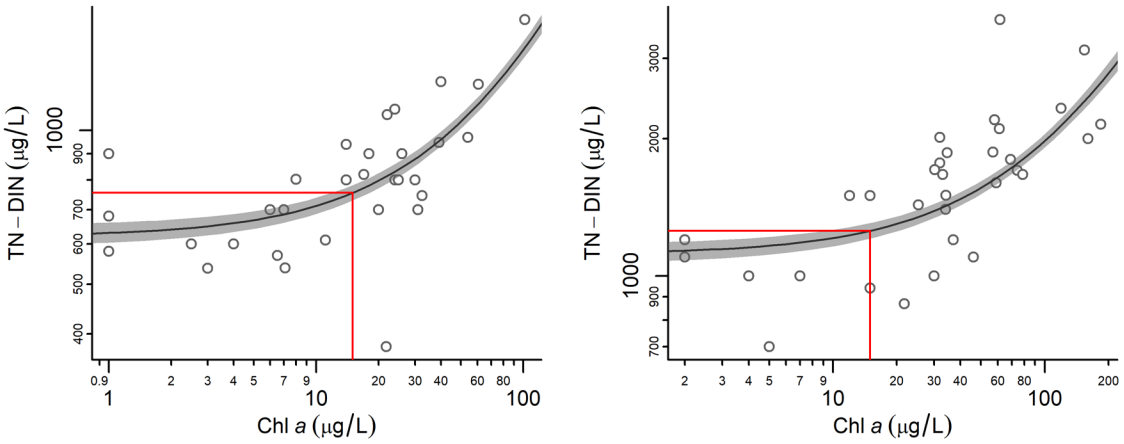

Figure 45. Lake-specific criteria derivation using combined Iowa-NLA model for two different lakes in Iowa. *Open circles*: observed values of TN-DIN and Chl *a* in Iowa for each lake; *gray shading*: 50% credible intervals about the mean relationship; *solid line*: mean relationship calculated using mean DOC concentration in lake; *horizontal and vertical line segments*: TN criterion calculation for illustrative Chl *a* target of 15 µg/L.

Appendix D: Operational Numeric Nutrient Criteria

Operationally, chlorophyll *a* (Chl *a*), total nitrogen (TN), and total phosphorus (TP) criteria can be specified to account for the effects of sampling and temporal variability on observed mean concentrations (Barnett and O'Hagan 1997). In most cases, the condition of a lake will be assessed by examining a small number of samples and the uncertainty in the estimation of the true seasonal mean value from those data will be determined by the number of samples, the temporal variability of nutrient concentrations in the lake, and the inherent sampling variability of the measurement. By examining historical data from many different lakes, sampling variability associated with Chl *a*, TN, and TP can be estimated and "operational" criteria can be specified to account for this variability with adjusted criterion magnitudes and by adopting a frequency component that allows for some excursions of the specified magnitude.

Ambient monitoring of nutrient concentrations provides the basis for determining whether a lake complies with the specified numeric nutrient criteria. Because of logistical and resource restrictions, the number of water quality samples available at different lakes can vary from a single grab sample to weekly or monthly samples throughout the sampling season. Statewide monitoring designs also vary in how often a lake is visited in different years. For example, a typical rotating basin design might sample the same lake once every 5 years, whereas other lakes might be sampled every year. Because of the differences in the frequency of sample collection, a statistical analysis of available monitoring data might be necessary to accurately assess compliance with the numeric nutrient criteria. This appendix describes a statistical approach for deriving *operational* or *realizable* criteria magnitude, duration, and frequency components.

This document provides tools to compute numeric nutrient criteria expressed as seasonal mean values. Those criteria implicitly assumed that a large number of samples are available for characterizing the condition of each lake and that the uncertainty in the computation of the mean value is small (Barnett and O'Hagan 1997), a condition that is usually not satisfied by routine monitoring data. Operational criteria incorporate statistical uncertainty in estimating environmental conditions from a much smaller number of samples. The statistical approach

recommended here requires that one estimate the sampling and temporal variability of nutrient concentrations within lakes for which criteria are specified.

A variety of approaches are available that account for within-lake variability when defining operational criteria, but they should all be designed to consider that nutrient concentrations vary in space (e.g., at different points on a lake) and in time. Both sources of variability account for a distribution of nutrient concentrations that will arise when a lake is repeatedly sampled. For example, if a single sample of TP was collected from one lake every year, over 10 years, the distribution of values might be as shown in Figure 46, in which observed concentrations range from 30 to 80 micrograms per liter (μg/L). Given this example, the water quality management question is whether the lake complies with its specified numeric nutrient criteria. Here, if the criterion is 60 μg/L, a methodical approach for assessing compliance can enhance the utility of the criterion. This section provides one example of an approach for accounting for sampling variability and defining "operational" nutrient criteria.

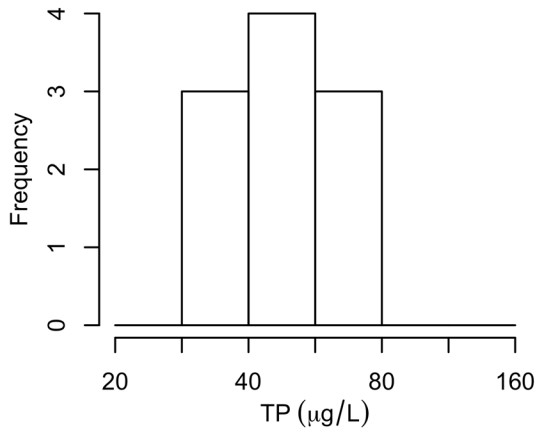

Figure 46. Example distribution of 10 TP measurements. Note that the horizontal axis is log-scaled.

Estimates of variability of measurements within lakes are needed to inform decisions on operational criteria, and those estimates can be computed from historical data. For this example, EPA analyzed TP data extracted from the Storage and Retrieval Data Warehouse (STORET) that had been collected in the summers from 1990 to 2011. From those data, lakes were identified in the United States with at least 5 years of nutrient data, yielding 25,056 samples collected from 846 different lakes. In this illustrative example, all available data were used, but screening data to identify lakes with relatively lower levels of anthropogenic nutrient

loading may be advisable. A statistical model was then used to estimate variance in nutrient measurements across different samples collected in the same year and from the same lake (within-lake variability). A model was fit to TP measurements that explicitly estimated intra-annual and interannual variability as follows:

$$\log(TP_i) = a_{j[i]} + b_{k[i]} + r_i \quad (42)$$

where TP_i is measured in sample i at site j and in year k. So, observed TP in a sample is modeled as being log-normally distributed about a mean value that is the sum of an overall site mean (a_j) and a random effect of year (b_k). The random effect of year is assumed to be normally distributed with a mean value of 0 and a standard deviation of s_{year}, and the intra-annual variance (r_i) is modeled as a normal distribution with a mean of 0 and a standard deviation of s_{sample}. Intra-annual variance not only includes contributions from traditional sources of sampling variability (e.g., measurement uncertainty), but also includes variability that could be attributed to differences in TP concentrations among different locations in a lake and differences in TP concentrations one might observe over the course of a single sampling season. Hence, intra-annual variance was expected to differ among different lakes, so, the overall distribution of different values of s_{sample} was modeled as a half-Cauchy distribution (Gelman 2006).

Fitting this model to the TP data collected from STORET yielded a mean estimate of 0.15 for the standard deviation of intra-annual variability of log(TP). Among different lakes in the data set, this value ranged from 0.10 to 0.27, so sampling variability varied substantially among the lakes in the data set. Estimating intra-annual variability from local data collected in the lake of interest would help ensure that the estimate correctly reflects variability in the lake. The mean standard deviation of inter-annual variability was 0.11.

Once intra- and inter-annual variability for the lake or lakes of interest has been estimated, this information can be combined with the criterion for that lake to estimate a distribution of nutrient concentration values that would be observed if the lake complied with the criterion. For example, if the standard deviation of the intra-annual variability of log(TP) in a particular lake is estimated as 0.15 and the inter-annual variability is estimated as 0.11, the combined variability is the square root of $0.15^2 + 0.11^2$, or 0.19. For illustrative purposes, if we assume the TP criterion for the lake is 60 µg/L, we can infer the characteristics of the cumulative distribution of single observations of TP that would be observed at the lake if it were exactly complying with its criterion (Figure 47). Then, based on this distribution, operational criteria can be derived. For

example, one might define an operational criterion that corresponds with the 10th percentile of the distribution (TP = 34 µg/L) and assert that a single TP observation below that value indicates the probability that the mean TP concentration in the lake is greater than 60 µg/L is less than 10%. That is, a lake with an observation below that threshold is likely in compliance with the criterion. Conversely, one might define a criterion at the 90th percentile of the distribution (TP = 105 µg/L) and assert that a single TP observation that exceeds that value indicates the probability that the mean TP concentration is lower than 60 µg/L is less than 10%. That is, any lakes with an observation that exceeds that threshold is likely to be out of compliance with the criterion. Different water quality management outcomes (e.g., additional sampling) could be triggered at different threshold concentrations. Also, different operational criteria can be developed depending on probabilities of error that are acceptable to environmental managers.

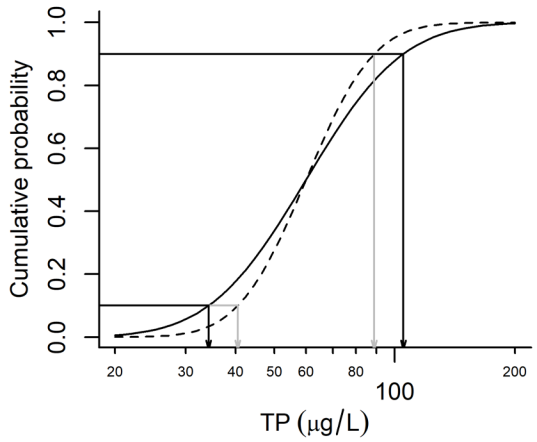

Figure 47. Example of defining an operational criterion magnitude. *Solid line*: the cumulative probability of observing a single sample TP lower than or equal to the indicated value if the true annual mean was exactly equal to the criterion (TP = 60 µg/L); *dashed line*: the cumulative probability for the average of four samples; *black arrows*: operational criteria for one sample; *gray arrows*: operational criteria associated with the mean of four samples.

This analysis also highlights the relative benefits of collecting additional samples from each lake. More specifically, the combined standard error (*s.e.*) on the estimate of a summer mean concentration is as follows:

$$s.e. = \sqrt{\frac{s^2_{sample}}{N} + s^2_{interannual}} \quad (43)$$

where N is the number of samples collected, s_{sample} is the sampling variability of the nutrient concentration (estimated as an intra-annual standard deviation), and $s_{interannual}$ is the inter-annual standard deviation. Hence, additional samples increase the precision with which the annual average nutrient concentration can be estimated by reducing the effect of intra-annual variability. In Figure 47, the dashed line shows the cumulative probability distribution of mean values computed using four samples. Because of the reduction in the standard error, assessments for compliance can be made with much greater confidence. The same 10% probabilities used above for single samples yield operational criteria of 41 µg/L and 89 µg/L, when applied to the case of the mean of four measurements (gray arrows in Figure 47). Information and procedures regarding the use of operational criteria in assessment might be described in a state's assessment methodology to accompany criteria specified in the water quality standards.

Appendix E: Example Workflow for Deriving Lake Nutrient Criteria

To further assist states and authorized tribes, an example workflow for deriving numeric nutrient criteria for a lake or reservoir is illustrated in this appendix by working through the case for a hypothetical Lake XYZ. The location of the lake is selected for illustrative purposes only, and the characteristics of Lake XYZ (e.g., depth, ecoregion, location, elevation) do not correspond to an actual location in the United States. Frequently Asked Questions (FAQs) are also included in each of the steps.

E.1 Identify Designated Uses

Designated uses for Lake XYZ are aquatic life protection and recreation. For aquatic life, a reproducing population of cool water fish are present. For recreation, swimming in the lake is a common summer activity.

E.2 Compile Data

The maximum depth of Lake XYZ is 10 meters (m), and on average, the thermocline in the summer is located 3 m below the surface. Mean dissolved organic carbon (DOC) concentration is 5 milligrams per liter (mg/L). The lake is located at 42.5 °N, 83.5 °W at an elevation of 1500 m. The lake is located in Ecoregion 55, the Eastern Cornbelt Plains. Cool-water fish species in the lake can tolerate temperatures up to 19° Celsius (C) and dissolved oxygen (DO) down to 4 mg/L.

FAQs:

1. *How do I measure depth below the thermocline?*
   Depth below the thermocline is best estimated by examining vertical profiles of temperature and estimating the depth of the thermocline as the shallowest depth where the temperature gradient exceeds 1° C/m. Depth below the thermocline can then be calculated as the difference between maximum depth and thermocline.
2. *What do I do with multiple measurements of depth?*
   Lakes vary in depth depending on location, but to be consistent with measurements collected by the National Lakes Assessment, depth can be recorded as the maximum

depth in natural lakes and the midpoint of reservoirs. Thermocline depth varies with the day of sampling, so if data from different days are available, a seasonal average thermocline depth can be used in the models.

3. *How do I develop statewide criteria from lake-specific numbers?*

   The models provide a way to calculate criterion values based on factors that may vary among lakes in a state (e.g., depth, ecoregion, DOC). Different options are available for computing statewide criteria depending on how much these factors vary within a state, ranging from lake-specific criteria to a single set of criterion values that applies to all lakes. Analysis to examine the range of nutrient criteria associated with different lakes in a state can inform these decisions. For example, if a large range of lake depths are found in a state, and criterion values differ widely among those lakes, then specifying criteria by depth class may be appropriate. The criterion models provide a tool for directly quantifying the effects of differences in lake characteristics on criterion values.

4. *How do I derive criteria when data needed by the models are missing?*

   Data for specific parameters (e.g., DOC) may not be available for every lake, but often information regarding the distribution of parameter values within a state or ecoregion can be estimated. For example, if the mean and standard deviation of DOC in a state or ecoregion can be computed, then this distributional information can be used to specify a range of lake nutrient criteria.

E.3 Management Decisions

For comparison, criterion values were calculated at three certainty levels: 50%, 80%, and 90%. Decisions were also required to determine the desired allowable probability of microcystin exceeding the recreational threshold of 8 micrograms per liter (µg/L), the size of the cool-water refuge, and the zooplankton slope threshold. A value of 1% was selected for the probability of exceeding the microcystin threshold, the cool-water refuge size was set at 0.3 m, and the zooplankton slope threshold was set at 0. The resulting candidate criteria are shown in the tables below (Table 6).

Table 6. Illustrative candidate Chl *a* criteria (µg/L) for Lake XYZ.

Certainty level	Aquatic life		Recreation
	Zooplankton biomass	Hypoxia	
50%	21	15	22
80%	14	12	9
90%	13	11	6

The tabulated values provide insights into both the most sensitive use in the lake and the uncertainty in chlorophyll *a* (Chl *a*) criteria associated with protecting that use. The candidate Chl *a* criterion for hypoxia is the lowest among uses at a certainty level of 50%, whereas candidate Chl *a* criteria for recreation are the lowest among uses for certainty levels of 80% and 90%. Among certainty levels, the range of Chl *a* criterion values is greatest for recreation, indicating that the sensitivity of certainty level to different criterion values is low relative to the other responses and uses. That is, small changes in the Chl *a* criterion are associated with small changes in the certainty level for this response. For hypoxia, the range of criterion values is narrow, indicating higher sensitivity. Here, small changes in the Chl *a* criterion are associated with relatively large changes in certainty level. Finally, the food web implications associated with lakes in which Chl *a* exceeds the level at which log(Z)/log(P) = 0 over the long term may be substantial and difficult to reverse, and therefore, the use of the 90% certainty level is recommended for this response to provide assurance that the candidate Chl *a* criterion for this response is protective. Based on these considerations, a final Chl *a* criterion of 12 µg/L might be selected. This value is slightly less than the 90% certainty level for the zooplankton biomass endpoint and corresponds to the 80% certainty level for the hypoxia endpoint. The value also corresponds with the 72% certainty values for recreation. This Chl *a* criterion value is used to compute the total phosphorus (TP) and total nitrogen (TN) criteria in Table 7.

Table 7. Criteria for TP and TN corresponding to a Chl *a* criterion of 12 µg/L

Certainty level	TP (µg/L)	TN (µg/L)
50%	25	560
80%	24	540
90%	36	570

More generally, criteria could also be derived that are protective of different designated uses and applied to different lakes depending on the applicable uses, while ensuring that, for each lake, the most sensitive use is protected.

FAQs

1. *How do I select the certainty level?*

   The certainty level, or credible interval, specifies a range of possible criterion values within which the actual value lies with the specified probability. For example, the 50% certainty level implies that there is a 50% chance that the actual value is within the specified bounds (i.e., the 50% certainty level is bounded by the 25th and 75th percentiles of distribution of possible criteria). In other words, the selection of 50% certainty level indicates that 25% of possible criterion values lie on either side of the model's best prediction. Because the criterion is based on the lower bound of the 50% certainty level, there is a 25% chance that the derived criterion value is greater than the concentration needed to achieve the desired condition. That is, there is a 25% chance that the criterion is under-protective. More certainty on the criterion value is achieved by selecting greater certainty levels. For example, there is only a 5% chance that a criterion based on the 90% certainty level would be under-protective. The R Shiny apps provide transparent information regarding the effects of different levels of certainty and can provide a useful means of engaging with stakeholders regarding the risk management decisions underlying criterion development.

2. *How do I select a slope threshold for the zooplankton model?*

   A value of zero for the slope threshold for the zooplankton model identifies the point at which changes in zooplankton biomass are not associated with changes in phytoplankton biomass. In other words, on average there is no increase in zooplankton biomass given a corresponding increase in their food source, phytoplankton. At this point the food web in a lake may be out of balance, an indication that aquatic life use may not be supported. States and authorized tribes may opt to select a higher threshold to provide additional assurance that aquatic life is protected in their lakes.

3. *How do I select a refuge depth for the hypoxia model?*

   Limited data are available on the refuge depth that is necessary to protect cool- and cold-water fish from the combined effects of hypoxia and increased temperature. The

studies cited in the criterion document include studies conducted in lakes with both deep water hypoxia and warm surface layer temperatures, and studies conducted in lakes with cool water inflows where fish have been observed to congregate. A minimum refugia depth of 0.3 m is identified in some of these studies. But the final selection for the refuge depth may also consider other factors, including the likelihood of a prolonged stable stratification in a lake with no mixing events and the likelihood of elevated temperatures in the surface layer through the end of the summer. States and authorized tribes may opt to select a larger refuge depth to provide additional assurance that aquatic life is protected in their lakes.

4. *How do I select the exceedance probability for microcystin?*

   The exceedance probability for microcystin can be interpreted directly in terms of the environmental outcome. That is, if mean Chl *a* concentration in a lake is maintained at the calculated criterion value, then the exceedance probability can be expressed in terms of the number of days of exceedance. For example, a 1% exceedance probability suggests that on average, microcystin will exceed the threshold concentration 1 day out of 100, so on average, 1 day in the swimming season for most states would not support recreational use of the lake. Furthermore, in Section 3.2.3.3, a method is described for translating the 1-day exceedance probability to a seasonal probability for a specified number of excursions during 10-day assessment windows [as specified in the recreational cyanotoxin criteria, (US EPA 2019)], and this information can further inform selection of the exceedance probability. As with the certainty level, the R Shiny app provides a transparent means of communicating the effects of different exceedance probabilities to interested stakeholders.

5. *How do I interpret slider values that do not yield criterion values?*

   Certain combinations of slider selections do not yield numeric criteria in the R Shiny apps and instead will return an error message. An example of this scenario occurs in the zooplankton model when a high slope threshold is selected with a high certainty level. When a desired slider combination does not yield a criterion value, consult with EPA to refine the model and possibly incorporate site-specific information.

E.4 Accounting for Interannual and Sampling Variance

Criterion values can account for sampling and temporal variability to increase the accuracy of compliance monitoring and to account for allowable exceedance frequencies of the criteria for Chl *a*, TN, and TP. Appendix D describes the statistical calculations for deriving operational criterion magnitudes and examples of those computations are shown below for the Chl *a* criterion. Based on the comparison of criterion values above, 12 µg/L was selected as the Chl *a* criterion. Intensive monitoring data at lakes similar to Lake XYZ indicate that the within-year standard deviation of $\log_e$(Chl *a*) in Lake XYZ is 0.8, while among-year standard deviation is 0.2. Given this information, the criterion magnitude can be adjusted to account for an allowable exceedance frequency. Here, to illustrate the approach, criterion magnitudes are calculated that can be exceeded once every 3 years.

To assess whether the lake is in compliance with a criterion value, we adjust the criterion magnitude as follows. First, calculate the combined standard deviation of Chl *a* measurements:

$$s_{comb} = \sqrt{s^2_{within-year} + s^2_{among-year}} = \sqrt{0.8^2 + 0.2^2} = 0.82 \quad (44)$$

For a once in 3 years exceedance frequency, calculate Chl *a* concentration that will be exceeded one-third of the time, assuming that Chl *a* measurements are log-normally distributed, with a mean value equal to the log-transformed criterion value, and a standard deviation equal to the combined standard deviation calculated above:

$$\log\left(C_{1\ in\ 3}\right) = \log\left(C\right) + z_{0.67}s_{comb} = \log(12) + 0.44(0.82) \quad (45)$$

Where $C_{1\ in\ 3}$ is the criterion value adjusted to an allowable one exceedance every 3 years, C is the criterion value of 12 µg/L, s_{comb} is computed above, and $z_{0.67}$ is the 67th percentile of the standard normal distribution (i.e., a 1 in 3 year frequency of exceedance). This calculation yields a value of 17 µg/L that is exceeded once every 3 years (assuming that a single sample of Chl *a* is collected each year and the mean Chl *a* concentration in the lake is equivalent to the criterion value of 12 µg/L). That is, if Lake XYZ was conforming exactly with the applicable criterion, then we would expect to see Chl *a* concentrations exceeding 17 µg/L in one-third of the years.

If several samples are combined to estimate each seasonal mean, the calculation for s_{comb} is adjusted to account for this averaging as follows:

$$s_{comb} = \sqrt{\frac{s^2_{within-year}}{N} + s^2_{among-year}} = \sqrt{\frac{0.8^2}{4} + 0.2^2} = 0.6 \quad (46)$$

Note: the numerical example shows the computation when four samples are averaged. Based on this adjustment, $C_{1\ in\ 3}$ for seasonal means computed as the average of four samples is 16 µg/L.

E.5 Incorporating State Data in National Models

Regular monitoring has been conducted at Lake XYZ and other lakes, in which a variety of water quality measurements are collected, and the state agency is interested in determining whether the state monitoring data can be combined with the national models to improve the accuracy and precision of the derived criteria. Several factors should be considered when making this decision:

1. *National models provide applicable criteria*.
   The criteria provided by the national criterion models apply to most lakes and reservoirs of the United States. The criterion models estimate relationships between measurements (e.g., Chl *a* and microcystin) that do not vary strongly with geographic location, and therefore, incorporation of state data may not appreciably change criterion values.
2. *Assess the inventory of observed data*.
   The measurements that are available in a state or tribal dataset should be compared with the variables that are included in the national models. Measurements of endpoint variables (i.e., microcystin, depth-averaged DO, zooplankton biomass, TP, and TN) and measurements of variables that account for large proportions of variability in these endpoints (i.e., Chl *a*, DOC, phytoplankton biomass, turbidity) need to be available for combining state and national data.
3. *Consider the likelihood of changes to national models*.
   Several factors determine the degree to which state data influence national relationships. Of these, two can be evaluated *a priori*. First, the number of samples collected for each parameter in the state data set should be no less than approximately 10% of the size of the national dataset. Second, relationships among variables can be more or less precise relative to the national data, depending on factors such as

differences in sampling protocols; however, state data that feature more precise relationships among variables of interest are more likely to influence the national model.

4. *Consult with EPA on statistical techniques for incorporating local monitoring data with national models*.

   Due to wide variations in the types of data that are collected, sampling protocols, and database formats, the process of combining state and national data is unique for each dataset. Therefore, EPA is ready to provide technical assistance to any state or authorized tribe that is interested in combining their data with the national criterion models as resources allow. Please contact your regional nutrient coordinator to request technical support through EPA's Nutrient Scientific Technical Exchange Partnership and Support (N-STEPS) program.

DEPARTMENT OF NATURAL RESOURCES

Minnesota Lake Plant Survey Manual

Version 4

For use by MNDNR Fisheries Section, EWR Lake Ecology Unit, EWR Minnesota Biological Survey Unit

14 March 2025









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How to cite this document

Perleberg, D., P. Radomski, S. Simon, K. Carlson, C. Schirmers, J. Knopik, and B. Holbrook. 2025. Minnesota Lake Plant Survey Manual, version 4. Minnesota Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN. 131 pages including Appendices A-D.

Purpose

For use by MNDNR Fisheries Section, EWR Lake Ecology Unit, EWR Minnesota Biological Survey Unit to assess lake habitat across the state.

Funding support

Development of this manual was supported by Game and Fish, Heritage Enhancement, and Clean Water Funds.

Acknowledgements

We thank MNDNR staff for their review and comments on earlier versions of this manual: Derek Anderson, Alex Binsfeld, Andrew Carlson, Karen Cieminksi, Donna Dustin, Peter Jacobson, Tom Jones, Pete Kvale, Steve Persons, Casey Schoenebeck, Welby Smith, Al Stevens, Courtney Sullivan, and Chip Welling.

Notes

This is the fourth revision of the original Manual (originally published on May 4, 2015). This version contains new information on woody habitat assessment (Chapter 9), aquatic botanical inventories and rare plant surveys (Chapter 10) and collection and preservation of aquatic plant specimens (Chapter 11).

For the purposes of this manual, the terms “aquatic plants” and “aquatic macrophytes” are considered the same and include vascular flowering plants, ferns and fern allies [example *Isoetes* spp. (quillworts), *Equisetum* spp. (horsetails)], liverworts (*Riccia* spp. and *Ricciocarpus* spp.), bryophytes, and macroalgae in the Characeae family. Emergent wetland plants that occur in the shoreline zone between the lake and upland are not generally included in MNDNR aquatic plant surveys except when they occur within aquatic sampling locations.

A note on measurement units. In Minnesota, most of the statewide lake hydrologic data have been recorded in English units. Specifically, lake depth contour data, lake area and shoreline length measurements available from MNDNR are recorded in feet. It is generally unnecessary to convert these data to metric units. Conversely, establishment of survey site locations in GIS and in-field navigation with GPS are primarily done using UTM (universal transverse Mercator) coordinates (meters) and likewise there is little reason to convert these data. Latitude – longitude are a standard for herbarium voucher specimens. Therefore, the data collection and reporting will be a mix of metric and English units.

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Chapter 1 Introduction

A tiered approach to statewide lake plant assessments

This manual provides a tiered approach to lake plant assessments where managers select protocols based on statewide and local priorities and objectives. These standardized protocols help ensure that appropriate data are collected in an objective, unbiased, and repeatable manner. Survey methods in this manual are science-based and are designed to identify and characterize in-lake and lakeshore habitat.

This manual was developed by MNDNR staff in Ecological and Water Resources (EWR) Lake Ecology Unit (LEU) and Minnesota Biological Survey Unit (MBS), in consultation with the MNDNR Fisheries Section. The manual was designed primarily for use by these groups, but protocols may also be used by other MNDNR Programs, other agencies and consultants. Various MNDNR programs, such as the Mississippi River Long Term Resource Monitoring Program, Wildlife Shallow Lakes Program, and Aquatic Invasive Species Program have specific protocols tailored to their individual survey objectives; some of their protocols are similar to those described in this manual, but staff should refer to Program-specific manuals (MNDNR 2011, Yin et al. 2000) when appropriate. This manual is divided into chapters based on different plant communities and survey objectives (Table 1-1).

Objectives for management and monitoring

The manual includes protocols focused on both inventory and monitoring. An inventory survey assesses the location or condition of a particular plant species or plant communities at a specific time. Data from these surveys can be used to compare plant communities in different lakes. These surveys may provide baseline or reference data for subsequent monitoring. They may also identify locations of rare species. If an inventory is well-designed, it may be repeated over time to assess plant community status and trends in the same location. Monitoring surveys are repeated over time to learn how plant species or communities within a lake vary over time. Monitoring may also be used to inform management and conservation. For example, a survey may be designed to learn how a management decision may influence a specific plant community. Inventory and monitoring data can be used to:

1. Learn more lake habitat and the habitat of specific plant species
2. Compare and contrast the plant communities of the surveyed lake with other Minnesota lakes
    a. Develop statewide and regional species distribution maps
    b. Identify lakes of high biological significance
    c. Identify lakes where plant community indicates potential impairment
3. Identify trends that may be used to predict future changes
    - Example: Is large-leaf pondweed distribution changing in Minnesota?
    - Example: How do ice and snow cover influence submerged plant growth?

4. Evaluate the effects of past management
5. Guide locations and scope of future surveys
6. Guide conservation activity of rare species and plant communities

The ability to detect habitat change depends on the magnitude of change that is of interest and the precision of estimates of change (Manley et al. 2006). Because the monitoring scale for each plant community will vary, the minimum change and precision standards will also vary. The manual outlines minimum sampling standards required to detect various levels of change and identifies situations where the sampling effort necessary to meet minimum standards may not be feasible. Additionally, there are some situations where a higher-than-minimum standard may be desired to detect subtle changes. Background information on plant sampling theory and design is provided in Appendix A.

Habitat specific protocols

Plant communities associated with lakes include:

- Terrestrial and wetland plants along shorelands (Chapter 3),
- Emergent and floating-leaf plants that are commonly found in near-shore shallow areas (Chapter 4)
- Submerged plants that may occur in both shallow and deep water (Chapters 5 and 6).
- Rare plant species whose habitats may include all the above (Chapter 9)

Different protocols are needed to assess each of these communities because they differ in:

- Logistical access to habitat (e.g., boat access vs. survey on foot)
- Botanical expertise required (e.g., general life form vs. species-level identification)
- Metrics (e.g., area covered by waterlilies vs. maximum depth of submerged plant growth)
- Methods and equipment required to measure metrics in different habitats (e.g., emergent and floating-leaf coverage vs. submerged plant occurrence)
- Temporal window of survey (e.g., trees can be assessed year-round while most species of submerged aquatic plants can only be assessed during open water growth period)

Prioritizing lakes for plant surveys

Prioritizing lakes for plant surveys is necessary to 1) ensure that data are representative of statewide plant communities and conditions, 2) ensure that data required for priority projects are collected, 3) maximize the limited staff time available for plant surveys, and 4) avoid duplication of effort among various survey programs.

In general, MNDNR prioritizes lakes with public access for surveys. Lake depth type (deep or shallow), lake surface area, development level, availability of existing recent data, and specific program goal are also used to prioritize lakes for field surveys. Because MNDNR Wildlife Shallow Lakes Program already assesses and manages shallow lakes, MNDNR Fisheries focuses their survey efforts on deep lakes. MNDNR EWR Programs survey both deep and shallow lakes in consultation with Fisheries and Wildlife to avoid duplication of efforts. Since 1993, Fisheries has prioritized lake plant surveys on a statewide basis with most game-fish lakes scheduled for a Transect Vegetation Survey (Ch. 5) on an approximate 10-year rotation. From 1995 to 2016, MBS conducted

over 2,000 lake plant surveys with a focus on lakes in central and northern Minnesota; current surveys continue to expand this geographic focus statewide.

These statewide data collections remain critical and are now also considered within the framework of the Minnesota Pollution Control Agency (MPCA) watershed assessment schedule, where water quality and biological conditions of lakes in each of the state's 80 major watersheds are assessed on a 10-year rotation. Individual Program priorities and special projects, such as MNDNR Sentinel Lakes, continue to influence survey priorities.

Table 1-1 Community specific methods to meet specific objectives

Chapter	Method	Community or Zone	Objective	Botanical Expertise	GIS Knowledge
3	Score The Shore (STS)	Shore	Rapid assessment of habitat	low	low
4	Floating and Emergent Plant Mapping (FLEM)	Shallow water plant stands	GIS-based delineation and dominant taxa classification	moderate	moderate
5	Vegetation Transect (VT)	Littoral zone	Compile lakewide taxa list and generalized geographic distribution of taxa	moderate	low
6	Point-Intercept (PI)	Littoral zone	Quantitative estimates of taxa distribution and frequency	moderate	low
7	Nearshore Vegetation Plots	Shallow water plant communities	Quantitative estimates of taxa distribution and frequency	high	low
8	Hydroacoustic Transect	Submerged plants	Quantitative estimate of plant height	low	moderate
9	Wood Habitat Survey	Littoral zone	Rapid assessment of wood pieces	low	moderate
10	Aquatic Botanical Inventory and Rare Plant Searches	Targeted lake habitats	Compile high quality botanical inventory list and locate rare species	high	low

Priority lakes and data for use in MPCA's Watershed Assessment

For MPCA's Watershed Assessment, MNDNR EWR has developed an Aquatic Plant Index of Biological Integrity (IBI) to assess lake plant health based on nutrient loadings (Radomski and Perleberg 2012). This tool requires a lakewide plant taxa list and utilizes data collected from multiple MNDNR survey programs, including Fisheries Lake Survey Program, LEU and MBS. Surveys that produce lakewide plant taxa lists (Ch.5, Ch.6, Ch. 7, or Ch. 9) are needed to assess each lake. Survey priority is given to larger lakes with high development and lakes where existing plant data indicates potential impairment (Figure 1-1). Surveys include lakes across the gradient of disturbance, from reference conditions to highly impacted sites. Lakes where recent quantitative plant surveys have been conducted will be given lower priority.

MNDNR EWR developed additional tools to assess lake plant health in response to shore disturbance. Score the Shore (Ch. 3) assesses shore habitat and Floating-leaf and Emergent Mapping (Ch. 4) assesses the distribution of emergent and floating-leaf plant stands. To effectively provide data for the watershed assessment projects, survey priority is given to larger lakes with high development (Figure 1.2).

Figure 1-1. For MPCA Watershed Assessment: Lake survey priorities to collect plant taxa list (Transect, Point-Intercept or Near-shore Plots)

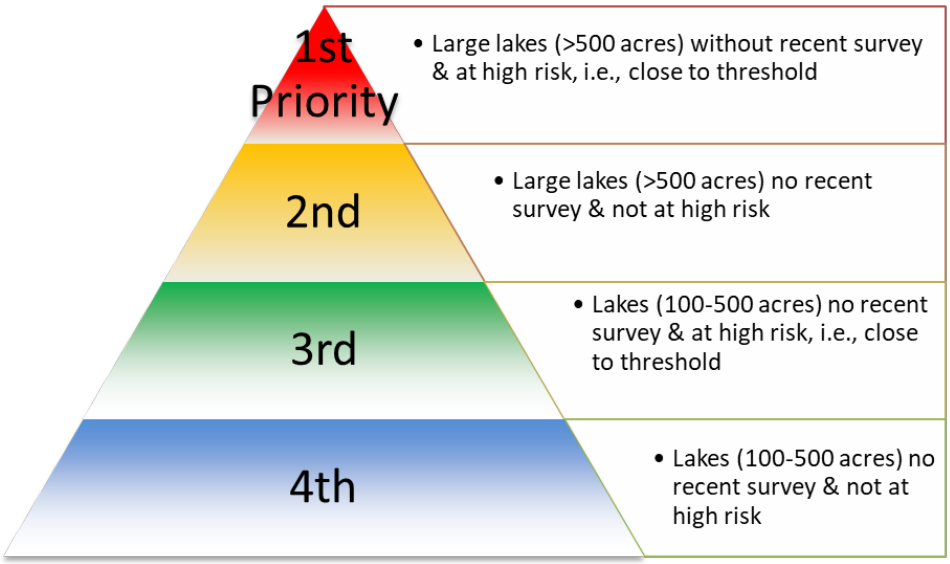
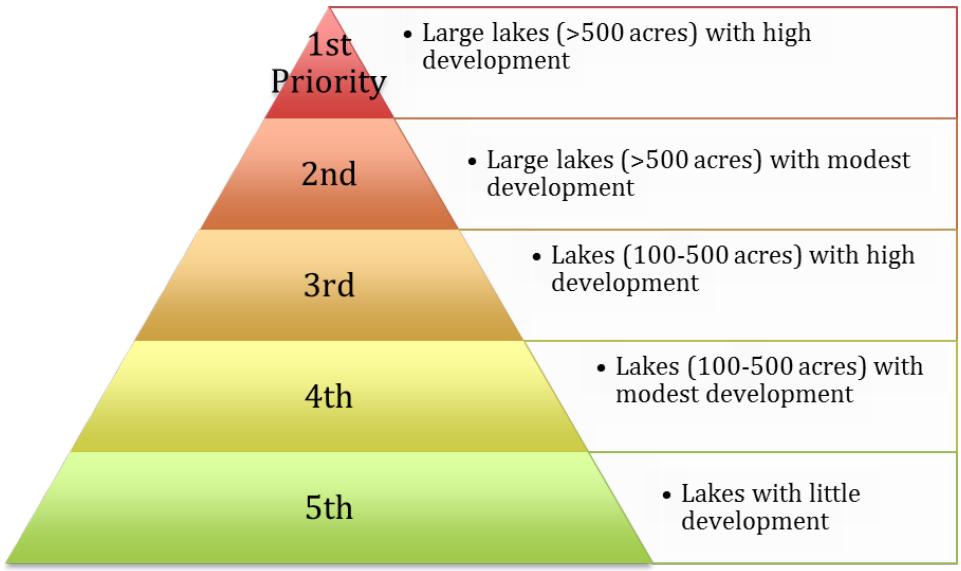


Figure 1-2. For MPCA Watershed Assessment: Prioritizing for Score The Shore surveys and Floating-leaf and Emergent Mapping surveys



Priority lakes and data for special survey projects

In addition to the annual set of prioritized lakes for MPCA Watershed Assessment, lakes may be surveyed on a more frequent basis because they are the focus of a statewide or Area-level project. Examples may include:

- Sentinel Lakes
- Lakes where changing conditions may result in vegetation changes
- Lakes where rare species have been documented, reported or where habitat conditions suggest they may occur
- Lakes where new county or state records have been reported or where habitat conditions suggest they may occur
- Lakes where surveys would facilitate better understanding of specific plants or plant communities
- Lakes with Lake Vegetation Management Plans (LVMP's)
- Lakes that are included in research projects

The survey method or methods used on these lakes will depend on the specific survey objectives.

Sampling timeline and survey frequency

Most vegetation sampling is conducted during peak growth and before plants senesce – typically from July through early September. Survey timing is dependent on survey objectives, specific growth conditions and life histories of target plants and individual lake characteristics. Lakewide submerged plant surveys are conducted after significant plant growth is noted in early summer. Depending on the life history of the species, rare aquatic

plant species surveys can be conducted from June through September. Surveys to delineate and describe emergent and floating-leaf plant stands and other unique plant areas are conducted from July through September. Shoreline habitat assessments can be done from early spring through fall. Because most of these surveys are conducted by boat, kayak or canoe, surveyors should select times when weather permits safe watercraft operation. Periods of higher winds and potential storms should be avoided. If feasible, surveyors should also avoid surveying on weekends and holidays when recreational boat activity is high.

It may not be feasible to assess all plants with one survey. If curly-leaf pondweed (*Potamogeton crispus*) is an important part of a lake plant community, surveys may be conducted in May or June, before this species senesces. Recent searches for macroalgae in the family Characeae suggest that spring or early summer surveys may be necessary to detect some species in lakes where water clarity declines by mid-summer. Annual species, such as wild rice (*Zizania palustris*) and bushy pondweeds (*Najas* spp.), however, may be missed in surveys conducted before July. In lakes with extensive wild rice stands, surveys to assess submerged plants may be conducted earlier (June) to minimize damage to wild rice.

The decision to repeat a survey and the frequency at which those repeat surveys are conducted are dependent on the specific objectives. For objectives relating to management, repeat surveys may not be a priority for undeveloped lakes where little change in development is anticipated and/or remote lakes that are logistically difficult to access. For lakes where monitoring change is a management priority, annual surveys may be warranted, particularly if lake conditions are expected to fluctuate on an annual basis. If annual monitoring is not feasible, or if significant changes are not detected with annual surveys, repeating surveys every 3 to 5 years may be sufficient. For management objectives related to MPCA's watershed approach, priority lakes should be surveyed every 10 years. For objectives relating to rare species, repeat visits, possibly in a single season, may be required for proper identification, collection and documentation.

Pre-planning

Checklists of required and recommended field equipment are provided in Appendix B. Specific survey method and plant identification training is available from LEU and MBS staff and can include formal workshops, printed and visual study aids, and in-field assistance. Remember to obtain any access permission and required collecting permits prior to survey.

Chapter 2 A Primer on Plant Sampling

Minnesota Lakes and Plant Communities



Glacial activity formed most Minnesota lakes and led to differences in the distribution, size and characteristics of lakes throughout the state. Differences in land-use across Minnesota have further influenced lake characteristics at the regional level. Minnesota lakes range in size from small ponds to waterbodies that exceed 100,000 acres in surface area. Northeast Minnesota lakes are generally deeper, oligotrophic systems with forested, minimally developed shorelands while southern Minnesota lakes are often shallow, nutrient-rich systems within shorelands dominated by agriculture or other development. Moyle (1945) describes the major flora of Minnesota lakes as they relate to chemical properties of lakes.



MNDNR Fisheries manages more than 3,700 lakes, most of which are deep and dimictic, ranging from 25 to 305,000 acres with a mean surface area of 368 acres. MNDNR Wildlife manages an additional set of about 3,800 shallow lakes (maximum depth of 15 feet or less), ranging from 25 to 38,000 acres with a mean area of 235 acres. Other MNDNR programs such as Aquatic Plant Management (APM), Shoreland Restoration, Aquatic Management Area (AMA) and Invasive Species Program (ISP) are involved in site level and lakewide plant management activities in both deep and shallow lakes.

Because of the wide range in plant abundance and diversity across Minnesota lakes, and the variety of program level survey objectives, it can be challenging to select survey methods that are appropriate for all lakes and all projects. Visual observation may be useful in clear lakes of northern Minnesota but not feasible in more turbid lakes in the south. Rake tosses are useful for sampling submerged vegetation but can be destructive in emergent stands of wild rice. A grid placement of points may be an efficient way to sample a broad littoral zone in a mesotrophic lake but not in a sparsely vegetated oligotrophic lake with a narrow littoral zone. To compensate for some of these difficulties, the manual provides a suite of survey methods targeted at specific plant community types. The general protocols are designed for the most frequently encountered plant communities. Special circumstances where protocols may need to be altered are discussed.

Measuring lake plant community attributes

Plant surveys can measure a variety of community attributes including plant distribution (the location and arrangement of plants throughout the lake), abundance (the amount of vegetation) and composition (the types of plants present). There are numerous methods to assess each attribute, but the approaches are not equal in the time, expertise and equipment required to conduct each survey or their ability to generate reliable estimates. The manual includes methods that can be used at a statewide scale, by non-botanists and that can be conducted relatively rapidly.

Quantitative data that are collected in a statistically valid manner are required to assess changes in plant communities over time or in response to management activities (Madsen and Bloomfield 1993, Spencer and Whitehand 1993). In designing quantitative vegetation surveys, it is important to consider survey objectives and available resources which will help determine the best method. Other considerations include the appropriate number of sample sites, area of each sample site, and arrangement of sample sites throughout the study area.



There are several standard ways to quantify plant abundance including biomass, cover, plant height, density, and frequency. Each metric varies in complexity and usefulness in assessing aquatic systems. The specific methods required to estimate each metric differ in expense, time, equipment, precision, adaptability to aquatic systems, and surveyor expertise. For example, many quantitative plant sampling methods require SCUBA surveys to adequately sample aquatic plants. While advances have been made in remote sensing techniques, such as hydroacoustics, these methods require specialized equipment and training, post-processing of data, standardization, and lack the ability to identify plants to the species level. For lakewide aquatic plant surveys where species identification is a priority, boat-based sampling with rakes remains the simplest, fastest and most economical method of sampling.

Abundance

Abundance is a generic term to describe the amount of vegetation present within a given area. Standard quantitative measures of plant abundance include biomass, cover, density and frequency and each provides different information about the plant community. Sample quadrats are typically used to measure plant abundance, but the appropriate size, shape and number of quadrats varies with each metric. Survey effort and expertise required to collect each metric also vary.

Frequency of occurrence

Frequency of occurrence, or frequency, refers to the uniformity of a species in its distribution over an area. It is the number of sample sites where a plant is detected (Figure 2-1). Frequency of occurrence is defined as the percent of sample sites in which the target taxon is detected and reflects the probability of encountering that taxon at any location within a specified area (Greig-Smith 1983). Because no counting or estimating is involved, frequency of occurrence is a simple, objective and rapid measure that can be consistently collected by different surveyors; other advantages include the ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). Frequency data are recommended as an appropriate abundance estimate when studying long-term changes in communities (Nichols 1999).

Frequency data are a function of both plant dispersion and plant abundance. With georeferenced data, large changes in plant dispersion patterns can be detected by viewing frequency data in GIS. However, changes in abundance (cover, density, or biomass) can be more difficult to detect. It is also possible for plant abundance and/or plant dispersion to change without a detectable change in frequency (Figure 2-2).

Plot size, or the physical area sampled at each vegetation survey site, is important in frequency sampling because the size of the plot influences the probability of any taxa occurring within the plot. The optimal plot size for collecting frequency data decreases both with increasing spatial structure and with increasing number of plots per survey (Heywood and DeBacker 2007). The best sampling precision is reached for a particular taxon when it is present in 30% to 70% of the plots sampled; this distribution will provide the most sensitivity to changes in frequency (Elzinga et al. 2001). Frequency values of 100% generally indicate plot size exceeds the maximum size of gaps between individuals (Daubenmire 1968). If frequency data appear to not detect perceived changes in plant abundance, decreasing the plot size may result in better resolution (Figure 2-3).

Because frequency data are dependent on plot size, data must be reported with reference to plot size and plot size must be consistent between surveys if data are to be compared. Surveyors must be careful not to include plants observed outside the plot boundaries as “present” in the plot because by doing so, they are in effect increasing the plot size. This can be challenging for surveys where plot area is visually estimated and a quadrat sampler is not used to determine plot boundaries.

Figure 2-1. Example: plant density and frequency decrease from Year 1 to Year 2.

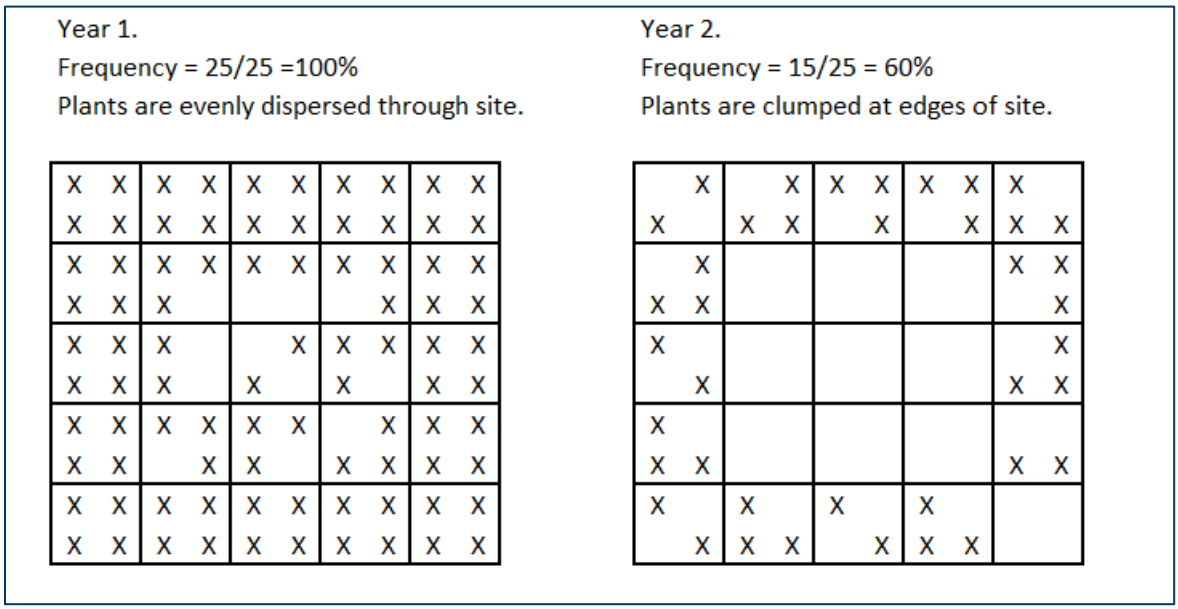


Figure 2-2. Example: plant density decreases from Year 1 to Year 2 but frequency does not change

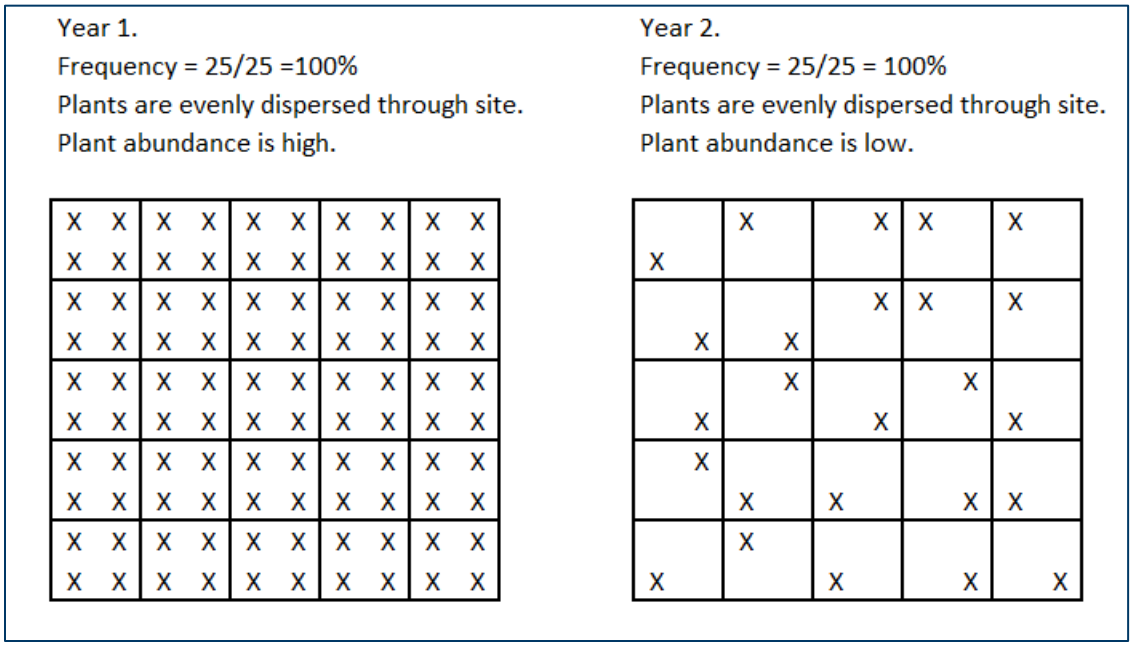
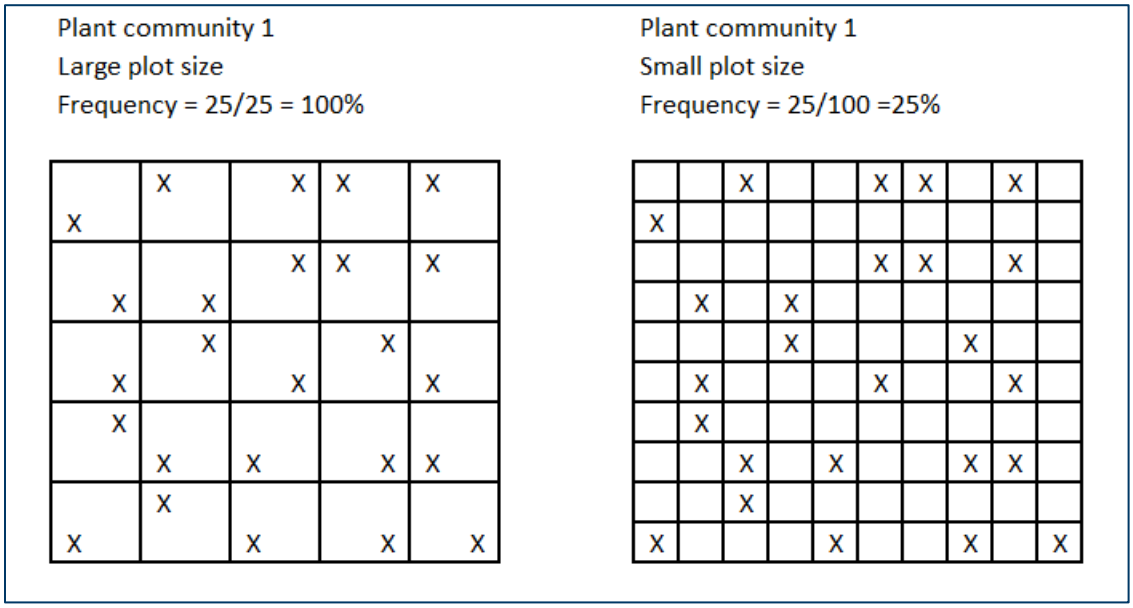


Figure 2-3. Example: survey area size is decreased for more accurate estimation of frequency



Coverage and cover

Coverage is the area covered by a plant community or stand. For example, emergent or floating-leaf stands may be inventoried by delineating the stand boundary. Cover is an estimation of how much a plant dominates an area. It may be estimated as the amount of the canopy or the ground occupied by the plant or as the proportion of the plant that extends into the soil (basal cover), or the vertical projection of the plant's exposed leaf area (foliar cover). Cover is estimated visually within quadrats, making it particularly difficult to estimate in deep water and/or turbid conditions. Because cover estimates are subjective, there is often variation between surveyors, and it is difficult to determine the accuracy of the estimate (Cheal 2008). Cover classes (e.g., 1-10%, 11-20%, etc.) reduce precision, but may increase surveyor repeatability. Obtaining accurate, repeatable estimates of plant cover can be difficult but errors can be minimized by using classes (Daubenmire 1959, Braun-Blanquet 1965). Hatton et al. (1986) found that in an artificial setting (paper illustrations), extremes of cover were estimated with less error than intermediate cover, and they therefore recommended that cover estimation classes be relatively narrow at the extremes and wider for intermediate ranges. They acknowledged that, in field settings, the actual ability of observers to estimate cover will vary.

Other estimates of abundance

Biomass – is the weight of living plant tissue and is the best single measure of a species' structural importance in a community. However, direct measurement can be difficult and damaging because it requires destructive harvesting of plants, both above and below-ground, particularly for species with extensive root systems. Madsen and Wersal (2012) discuss the tradeoffs between collecting many small biomass samples or fewer large biomass samples, with larger samples requiring more processing time.

Biomass sampling is labor intensive and includes cleaning and drying of plant material to obtain dry weight biomass; it is most often used for small survey area assessments to assess specific management activities rather than lakewide surveys (Madsen 1993). For time and cost reasons, biomass estimates are not recommended as a standard protocol.

Density – is the number of individuals, or number of stems, within an area. This measure may have little meaning if individuals of a species vary greatly in size. Sample quadrats are used to estimate density, but different size quadrats may be needed to adequately sample all plants in a community. For aquatic plants, it can be very difficult to define an individual or stem and density counts typically require SCUBA divers. For time and cost reasons, density estimates are not recommended as a standard protocol.

Mean Plant Height – is a measure of the mean of maximum plant heights of a submerged plant community using hydroacoustic survey techniques. This measure may be converted to a relative value, often called biovolume, by dividing by water depth. If the submerged macrophyte community has a consistent canopy without a scattering of taller plants, the average of the maximum plant height will be similar to the mean plant height. However, submerged plant communities with variable plant heights are common. Radomski and Holbrook (2015) studied two commonly used hydroacoustic systems and found differences in the estimates of mean plant height and frequency of plant occurrence. Their study indicated that standardization of data collection equipment and the signal processing approach is necessary prior to using this technology as an assessment tool. Standardization of the hydroacoustic system includes transducer frequency, beam angle, and signal processing. Second, the survey design would also need to address sampling timing and frequency. Third, surveyors need to consider whether the objective includes the creation of maps of mean plant height by depth strata or whether collecting data from a representative sample of the littoral area is sufficient. The former requires considerably more field survey time and resources.

Descriptive abundance rating

Descriptive abundance ratings are subjective, often visual estimates that have been used as a surrogate for quantitative abundance estimates (Madsen and Wersal 2012). Some aquatic plant survey protocols (Indiana Department of Natural Resources 2007, Harman et al. 2008, Hauxwell et al. 2010, Yin and Kreiling 2011) use some form of an abundance rating to overcome the labor intensity associated with biomass techniques and the requirement for direct visual surveys associated with cover and density estimates. Such abundance ratings attempt to combine plant height, plant density and plant cover to describe the amount of the water column occupied by vegetation. Samples are collected with a garden rake that is divided into discrete increments and when plants are harvested an abundance ranking is given for each species. Theoretically, tall plants with high cover and high density receive the highest rating because the rake sample would collect a large amount of plant material and short plants with low cover and low density would receive the lowest rating; plants with intermediate abundance features would receive intermediate ratings.

Deppe and Lathrop (1992), who pioneered the rake abundance rating method, noted that such visual estimates involve subjectivity, require additional field time and may be most appropriate for assessing short-term changes in general plant abundance as opposed to assessing individual plant species abundance. In a comparison of rake abundance ratings and diver-collected biomass samples, Johnson and Newman (2011) found that abundance ratings were significantly higher and less precise than biomass estimates and that the comparability of the two methods is dependent upon the dominant taxa present. Yin and Kreiling (2011) concluded the efficiency of the rake to collect biomass varied among species and correlations of visual density ratings with biomass may be appropriate only if confirmed by diver-collected biomass samples for each individual species. Harman et al. 2008 reached similar conclusions and found that the rake abundance ratings and dry weight biomass estimates were comparable in only 17% of the instances with results varied among species growth forms.

The amount of vegetation collected on a rake toss is not only dependent on plant height, density and cover, but by individual species growth form and the "catchability" of each plant type and different site conditions. Tall, branching plants are more readily collected by a rake toss than are non-branching plants, those commonly growing at low densities relative to other species, and those growing lower in the canopy relative to other species (Harman et al. 2008). For example, bulrush (*Schoenoplectus* spp.) plants have minimal leaf area and if a moderately dense bulrush stand is sampled by rake, it is likely that only a few leafless stems will be collected on a rake and the rake abundance rating will be low. Conversely, coontail (*Ceratophyllum demersum*) plants have leaves that are densely arranged along the stem; if sampled by rake, coontail is likely to fill a large portion of the rake regardless of whether one or multiple plants were present in the sample. Rake sampling is more effective in shallow water where surveyors can better manipulate the area of lake bottom sampled. As water depth increases, there is more uncertainty about how much, if any, of the actual sample site is sampled.

Because plant height, cover and density are not always related, it is not possible to relate an abundance rating back to the quantitative plant features. A high abundance rating may indicate that plants were tall and/or cover was high, and/or density was high. Abundance ratings at sites with sparse occurrences of high cover plants (ex. a single waterlily) may not be distinguished from sites with high density, low cover plants [ex. dense bulrush (*Schoenoplectus* spp.) stand].

Despite the subjectivity and uncertainty associated with descriptive abundance ratings, they can serve as supplemental information when collected as part of a quantitative survey. Reducing the number of ratings to a three level "high", "medium" and "low" scale can help minimize ambiguity. In the example shown in Figure 2-2, an abundance rating could help distinguish the Year 1 community, where frequency is high and an abundance rating may be high (many plants per site), from the Year 2 community, where frequency is high but an abundance rating may be low (fewer plants per site). Abundance ratings may also be used to identify potential lake areas where recreational lake use may conflict with aquatic plant growth (sites of high plant abundance ratings).

Habitat zone definitions

For this manual, Habitat Zones are defined as shown in Figure 2-4 and the following definitions are used:

Lakes are enclosed basins filled or partly filled with water; they may have an inlet and/or outlet stream or may be completely enclosed.

Lakewide refers to the area defined by the lake boundary. It is used to identify sampling that occurs at a broad level where the entire lake is the experimental unit.

Lakeshore is the area comprised of the Shoreland, Shoreline, and Aquatic Zones.

Shoreland is defined in Minnesota Rule 6120, which for lakes is that land located within 1000 feet of the ordinary high water level (OHWL). Some local governments use a distance of 1320 feet. The methods in this manual use land located within 1320 feet of the OHWL to encompass both definitions. For this manual, we divide the Shoreland into two zones; these zones are not defined in Rule and do not have distinct boundaries or distances but are distinguished here because they are often managed differently by riparian owners (see Chapter 2 for detailed definitions):

Shoreland Zone is the landward portion of the Shoreland.

Shoreline Zone is the lakeward portion of the Shoreland. It is the transition zone between the Shoreland and Aquatic zones.

Aquatic refers to the lake and is used to distinguish this area from surrounding wetlands and terrestrial uplands.

Littoral area is defined in Minnesota Rule 6216 as "any part of a body of water 15 feet deep or less." Biologically, it is the portion of the lake where light is available for aquatic macrophyte growth. The legal definition is useful because it provides a general standard that can be used as a statewide reference. However, the actual depth of plant growth may exceed 15 feet on many lakes and it may vary seasonally, annually and between lakes. For the purposes of this manual, we use the biological definition of littoral zone and use it to distinguish shallow, potentially vegetated aquatic areas from deep zones that do not support vegetation.

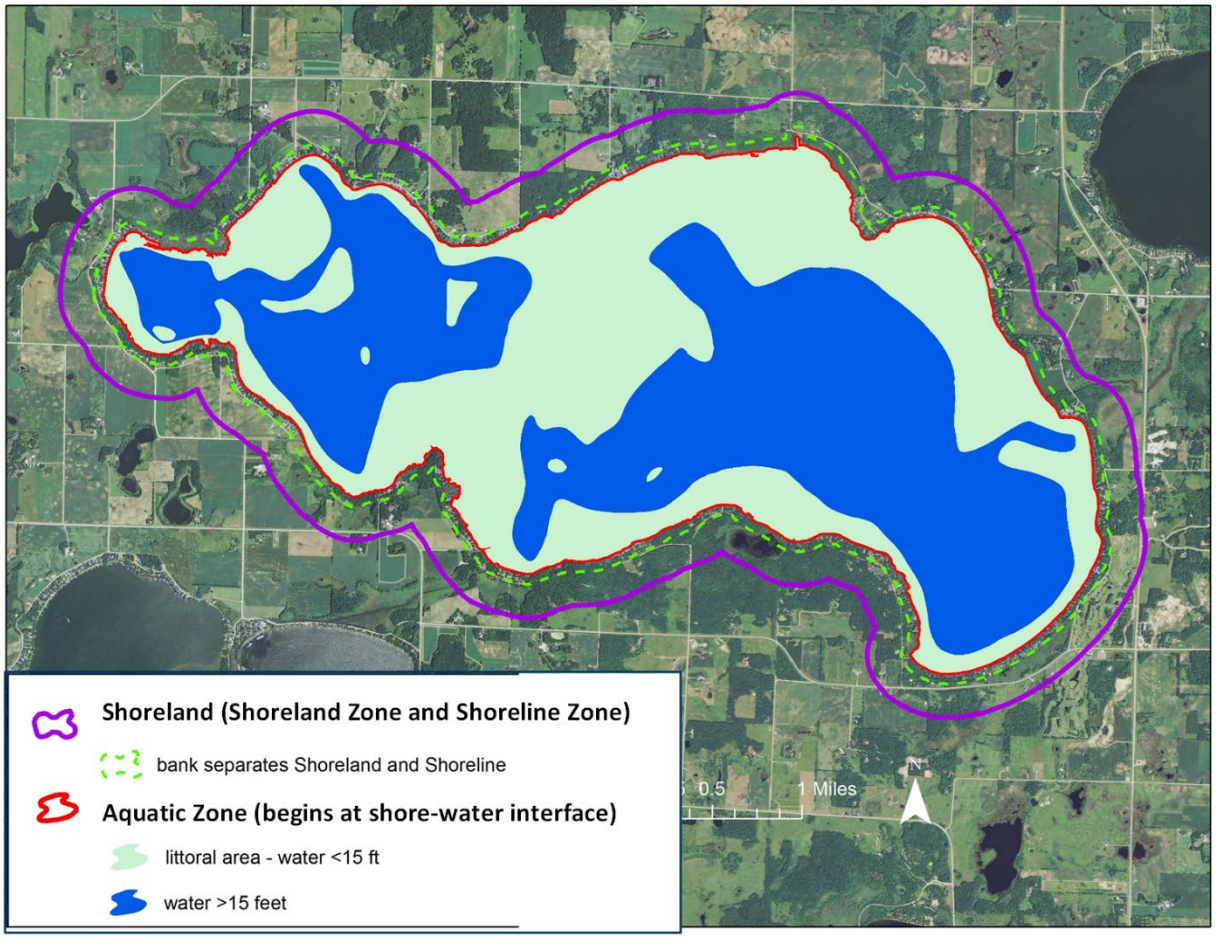
Near-shore is the shallow water area of the littoral area within a short distance of the shoreline where lake development impacts are likely to occur. Such impacts include dock installation, plant removal and woody habitat removal. This impact area varies within and between lakes because water depth can vary between sites but is generally less than 5 to 7 feet.

For Score The Shore surveys: Surveyors assess only a riparian portion (about 100 feet) of the shoreland. At developed sites, surveyors include only the area viewable from the lake and extending to the lakeward side of the structure. This area is then subdivided into the Shoreland and Shoreline Zones.

Surveyors also only assess a portion of the Aquatic Zone, generally the first 50 feet extending lakeward from the shore-water interface.

For Transect and Point-Intercept Surveys**:** Sample locations are established within the Aquatic Zone only and may extend beyond the standard littoral zone (15 feet).

Figure 2-4. Lake Habitat Zones



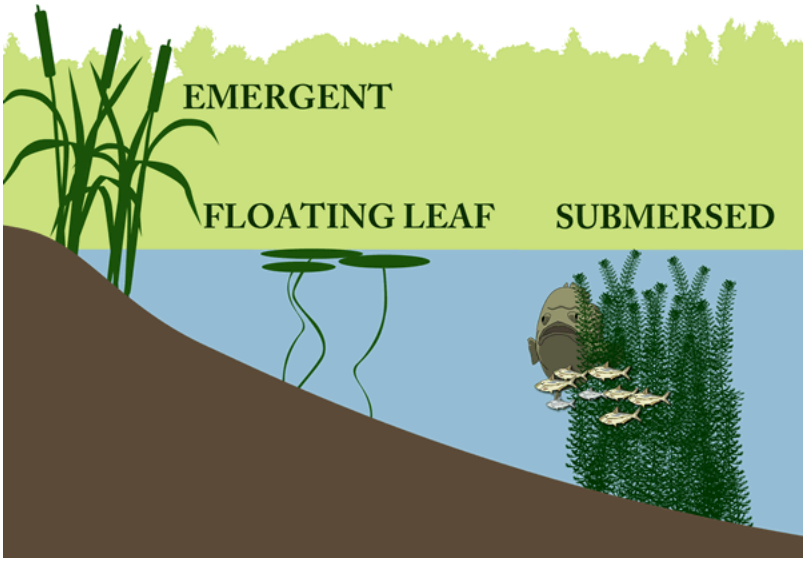
Types of aquatic plants

Aquatic macrophyte is defined in Minnesota Statute 84D.01 as "a macroscopic non-woody plant, either a submerged, floating leaved, floating, or emergent plant that naturally grows in water." Aquatic macrophytes include vascular flowering plants, mosses, ferns, and macroalgae in the *Characeae* family. These plants require hydric conditions for at least a portion of their life cycle.

Aquatic plant is defined in Minnesota Statute 84D.01 as "a plant, including algae and submerged, floating leaved, floating, or emergent plants, that naturally grows in water, saturated soils, or seasonally saturated soils."

For the purposes of this manual, the terms "aquatic plants" and "aquatic macrophytes" are considered the same. Emergent wetland plants that occur in the shoreline zone between the lake and upland are not generally included in MNDNR aquatic plant surveys except when they occur within aquatic sampling locations. Plants can be grouped based on where they grow in relation to the lake bottom and water surface, and Minnesota Statute 84D.01 defines four major lifeforms (Figure 2-5):

Figure 2-5. Aquatic Plant Life Forms



Emergent plants are rooted in the lake bottom, and during peak growth most of their leaves and/or stems extend out of the shallow water.

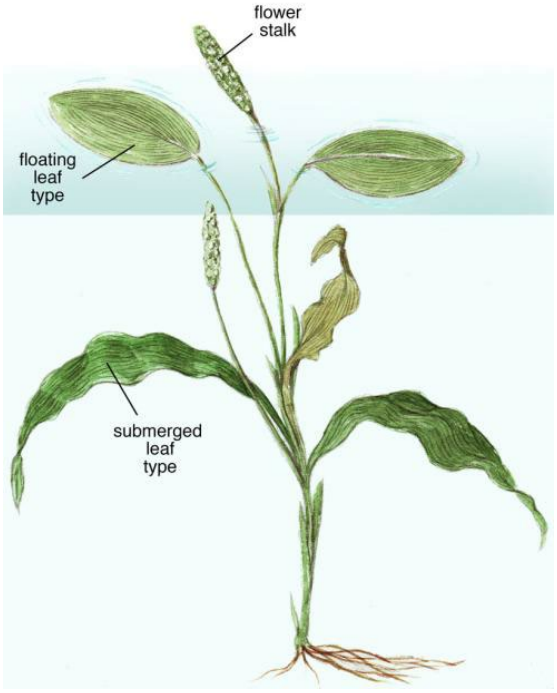
Floating-leaf plants are rooted on the lake bottom, and during peak growth their leaves and flowers float on or just above the water surface. Floating-leaf aquatic plants are defined in M.R. 6280.02 as "aquatic plants that are rooted in the bottom and have their lower portions submersed in water and leaves that float on the surface of the water including species in the genera *Nymphaea*, *Nuphar*, *Brasenia*, and *Nelumbo*. Species in the genera *Potamogeton*, *Callitriche*, and *Ranunculus*, which are submersed aquatic plants that may produce some floating leaves, are not included in this definition."

Submerged plants grow primarily under the water surface and may or may not be rooted in the lake bottom. Flowers of submerged plants may occur above or below the water surface. Many submerged plants are "heterophyllous" and have both submerged and floating leaves, but most vegetative growth is beneath the water surface (Figure 2-6). These heterophyllous plants are considered submerged. Plants such as coontail (*Ceratophyllum demersum*), bladderworts (*Utricularia* spp.), and macroalgae

(*Characeae*) that do not strongly attach to the lake bottom but have vegetative growth that occurs primarily below the surface are considered submerged.

Free-floating plants are not anchored to the lake bottom and have vegetative portions that primarily float on or just below the water surface. This group primarily includes duckweeds (*Lemnaceae*).

Figure 2-6. Heterophyllous aquatic plant



Submerged plants that can form floating leaves are grouped into the “Submerged” class for MNDNR aquatic plant surveys.

Image courtesy of MNDNR MnAqua Program

Chapter 3 Score The Shore: Rapid Assessment of Lakeshore Habitat

Objectives

Score The Shore is a protocol developed to rapidly assess the quantity and integrity of lakeshore habitat. The survey is designed to assess differences in habitat between lakes and to detect changes over time. Many of Minnesota's shorelands are under private ownership and this survey method may be used to assess both public and private lands. The MNDNR assesses conditions of private lands through various programs, some of which are done in cooperation with the landowner and others that are larger scale assessments that use remote sensing. Score The Shore surveys require visual observation of lands accessible by boat. The intent of this survey is to assess habitat, not to inspect for violations. Data are not tied to individual properties and will not be displayed at the individual lot level. A separate but similar survey titled "Score Your Shore" has been developed for riparian landowners to self-assess their developed lot (Perleberg et al. 2012). In Score Your Shore, the individual lake lot is the study site, and the survey area can vary based on lot size. In Score The Shore, the entire lakeshore serves as the study site. Specific objectives of the Score The Shore Survey are:

1. For each individual lake, determine the lakewide lakeshore habitat score with modest precision.
2. Detect substantial lakewide lakeshore habitat score changes (>20%) over time and monitor trends in lakeshore habitat.
3. Compare lakewide lakeshore habitat scores within and between watersheds and ecoregions to assess patterns and trends.

Introduction

The lakeshore is a transition zone that attracts a wide variety of birds and animals that move back and forth between the upland and water. It is a filtering zone that can trap sediments and nutrients as water flows from the upland into the lake. A natural Minnesota lakeshore may include a mix of live and dead trees, shrubs, wildflowers, grasses and rocks. Some depositional-zone shores have natural sand covering most or a portion of the site, with only scattered vegetation. Erosional-zone shorelines often have high banks and rocky substrates. Wind-protected bays and small lakes may have shorelines with organic sediments and rich plant communities. Upland trees hang over the water's edge and create shade and cooler water for fish and animals in the lake. But as people remove vegetation, this zone becomes destabilized and resulting erosion allows silt and sediment into the lake. In response to this, landowners may inappropriately opt to install riprap or retaining walls to prevent further erosion. Humans can also

alter the habitat in the lake itself. Installation of docks and other structures can reduce or alter the aquatic plant growth (Garrison et al. 2005). Emergent and floating-leaf plant beds are often reduced at developed sites (Radomski and Goeman 2001, Jennings et al. 2003). As Minnesota lakeshore zones are changed from “wild” naturally vegetated areas to “domesticated” sites of turf grass and hard surfaces, critical areas for wildlife and important filtering effects are lost.

Another important component of the lakeshore ecosystem is woody habitat that is created when whole trees, tree limbs, branches, twigs and leaves fall into the lake from the adjacent upland. Fish and other aquatic life use this woody habitat in a variety of ways: as shade from sunlight, refuge from predators, spawning and nesting sites, and for foraging. When lakeshore trees are cut for development, they are often removed from the site, reducing the potential for woody habitat to be added to the aquatic zone. Homeowners often remove existing woody habitat (Francis and Schindler 2006) and may not realize that these materials provide critical habitat.

Many Minnesota lakeshores have been altered by human activities, but describing, quantifying and comparing these alterations statewide can be challenging. As narrow transition zones, lakeshores are often not included in landscape assessments unless they are part of a larger contiguous land tract. Aerial photography can assess major vegetation changes such as deforestation, but subtle changes in forest understory are more difficult to detect. Because many lakeshores are divided into small, private ownership tracts, field assessments are logistically complicated.

Survey design

This is a rapid assessment method in which surveyors assess the amount of vegetation and other features within zones of the lakeshore. This survey is designed to be conducted from a boat not only because of property ownership issues but to provide for a rapid assessment. Even at lakes with publicly owned shoreline or with the permission of a private property owner, surveyors should view the survey area from the boat to retain consistency between survey sites. This survey is designed for lakes with shoreline lengths of 50 miles or less. It can be conducted on large lakes, such as Mille Lacs, Leech, and Rainy, but it may be useful to target specific bays or shorelines on these large lakes rather than attempting to survey the entire shoreline.

The entire lake is the unit of analysis, and the sampling zone includes portions of the upland and aquatic zones and the transition zone between them. Survey sites are established in a systematic, regular interval along the lake perimeter and are independent of property ownership. At each survey site, three habitat zones are independently assessed, or scored, based on specific features related to habitat. Higher scores indicate a greater amount of natural habitat. Lower scores indicate a low percent of the site remains natural and a higher amount has been physically disturbed or altered by humans. The feature scores within each zone are summed for an overall Site Habitat Score. This scoring process provides a simple method of ranking sites based on the percent of each site that is in a natural condition versus the percent of the site that has been altered.

A lakewide score is calculated using the mean Site Habitat Score. Scores range from 0 to 100 and lakes with a high percentage of unaltered habitat score higher than lakes that have been highly altered. Because lakes are often not developed in a regular pattern (for example, the north shore may be entirely developed while the south shore is undeveloped), a lakewide score may be high but some individual sites may score low.

Establishing survey sites

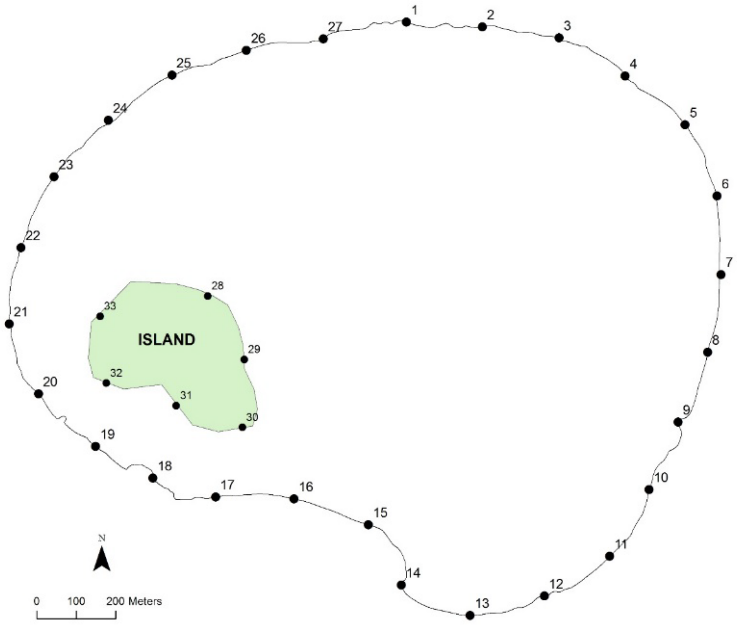
Each individual survey site is a 30.5-meter (100 feet) shoreline segment. The recommended minimum number of survey sites per lake is 20, which results in at least 610 meters of shoreline assessed on each lake; on all lakes at least 8% of the entire shoreline is assessed. The spacing of survey sites, and therefore the total number of survey sites and percentage of shoreline assessed, are determined by the length of the shoreline (Table 3-1). On lakes with 3.3 to 15 miles of shoreline (which accounts for most Fisheries-managed lakes in Minnesota), survey sites are spaced 200 meters apart. This results in an assessment of 17% of the total shoreline (i.e., 33 meters of every 200-meter segment, or 17%, is assessed). Survey sites are spaced closer together on lakes with less than 3.3 shoreline miles and further apart on lakes with more than 50 shoreline miles. On very small lakes with less than 1.22 shoreline miles, surveyors place 20 survey sites at equal distances around the shoreline and that distance may range from 60 to 95 meters.

Table 3-1. Determining the Score the Shore survey site spacing based on shoreline miles

Shoreline length (miles)	Spacing of sites (meters)	Number of points per lake	Survey segment length (meters)	Percent of Lakeshore Surveyed
0.75-1.21	60 to 95	20	30.5	35 to 55
1.22-2.24	100	20-36	30.5	33
2.25-3.29	150	24-35	30.5	22
3.30-14.99	200	27-121	30.5	17
15.00-50.00	400	60-201	30.5	8

GIS software is used to create center points of these shoreline segments at equal intervals around the lake perimeter (Figure 3-1). A GIS tool has been created to automate the point creation (refer to GIS Manual). If a Shore The Shore survey has been previously conducted on a lake, then surveyors should reuse the original survey site locations.

Figure 3-1. Score The Shore survey site placement along shore (Example lake with 4.5 shoreline miles (including island perimeter). Survey points are spaced 200 meters apart.)



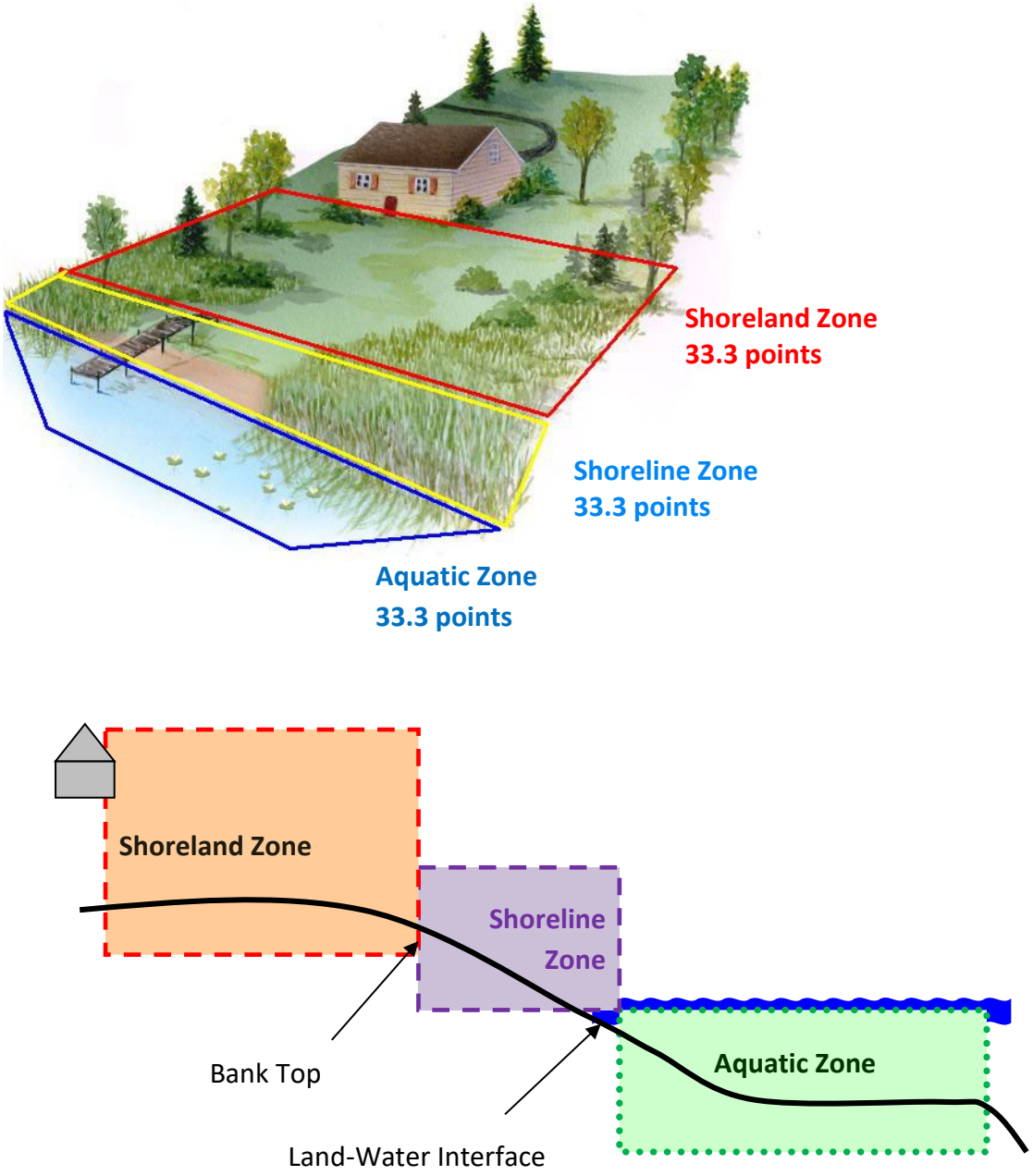
Assessment of habitat by zones

Surveyors use standard criteria to divide the lakeshore into three zones: Shoreland, Shoreline and Aquatic (Figure 3-2). Because physical measurements are not used to determine the boundaries, it is important for surveyors to practice delineating these zones using photographs of example sites. Given that these protocols are designed for rapid assessment, the boundaries of each zone are approximate.

The landward portion of the site is divided into the Shoreland and the Shoreline Zones. If a bank is present, it can be used as a visual separation between the Shoreland and Shoreline Zones with the Shoreland beginning at the top of the bank and continuing landward and the Shoreline beginning at the bank and extending to the water's edge. If there is no slope or a very gradual slope, surveyors use their best judgment to divide the land zone into the 2/3 Shoreland and 1/3 Shoreline Zones. Compared to the Shoreline Zone, the Shoreland Zone often extends a greater distance landward, but each zone's dimensions will vary based on slope.

Because assessments are conducted visually by boat, surveyors are limited to assessing only two dimensions of each site: the length of the site (the 100 feet segment), and the height of vegetation. The third dimension, the landward extent of habitat, is not assessed. In effect, when surveyors photograph the site, the image provides the two-dimensional view that will be assessed. Another way to consider this is to assess the percent of the site that is "screened" by vegetation. The "landward depth" of that screen, which is the third dimension, is not assessed.

Figure 3-2. Score The Shore habitat zones



Visual estimation of plant cover

Surveyors make visual estimates of the survey area boundaries and vegetation cover. Broad categories of plant life forms (trees, shrubs, ground cover) are evaluated and plant taxa identification is not required. Surveys are conducted between May and mid-October when upland vegetation is present. Depending on specific objectives, surveys may be targeted for specific dates within that time.

Because surveyors are estimating cover for a wide range of plant life forms (trees, shrubs and ground cover), broad cover classes are used for the entire range of cover. To improve accuracy and repeatability associated with plant cover estimates, cover classes are broad (25% increments), and neighboring cover classes have small differences in point scores. For example, while estimating tree cover in the Shoreland Zone, if surveyor A selects the cover class 25-49% and surveyor B selects 50-74%, their final scores will only differ by three points. The goal of this survey is focused on detecting large differences in habitat. For example, if Shoreland tree cover at Site X is 75-100% but only 1-24% at Site Y, the final scores for those sites will differ by at least 10 points.

While developing this method, surveyors expressed high confidence in their ability to accurately assess cover when the site was near the extremes of the cover range (sites that had very little vegetation and sites that had very little disturbance). At sites of intermediate plant coverage, surveyors were less confident of their coverage assessments and took longer to arrive at a final estimate.

Pre-survey preparation

Training

LEU provides annual Score the Shore Survey training that includes a classroom portion and on the water survey experience. A “pre-survey” standardization should be conducted to help ensure that all surveyors are recording similar information when they observe a site. A refresher training presentation is provided in Appendix D. This includes a set of shoreland photographs for surveyors to view and independently “score”. The survey organizers should review the results and select sites for group discussion. It is particularly important to discuss sites where surveyors did not agree on scores. This “trial run” of the actual survey provides an opportunity for surveyors to better understand how to score each feature within the three Zones.

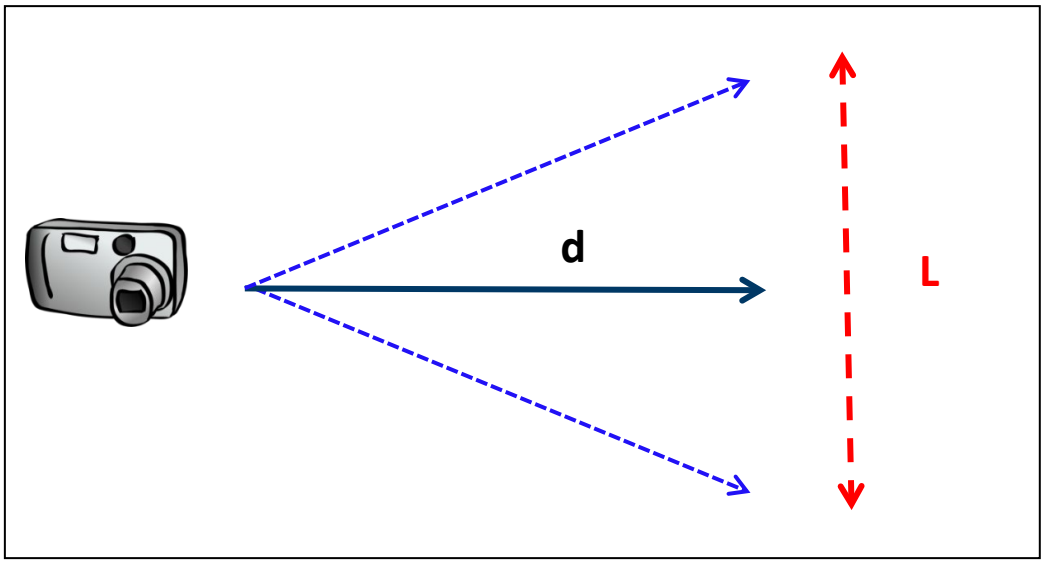
Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix A. Data are entered electronically or on paper forms (Appendix B). Survey point waypoints are created in GIS and uploaded to GPS units (GIS Manual).

For photo-points, surveyors should pre-determine the field of view for the specific camera they use and ensure that the entire 100 feet of shoreline is included (Figure 3-3). For example, the Garmin Montana Surveyors should predetermine the distance from which they need to photograph the survey site to include about 100 feet (30.5 meters) of lakeshore in the photograph. For Garmin Montana cameras and iPad cameras, that distance is approximately 100 feet or 30.5 meters

GPS camera and an iPad camera will photograph about 100 feet of shoreline when the photographer is stationed about 100 feet (30.5 meters) from shore.

Figure 3-3. Determining field of view for camera (d = distance from camera to midpoint of photographed image, L = length of photographed image)



Conducting the survey

The preferred data collection method for this survey is electronic data collection using Collector for ArcGIS on an iPad contained in a waterproof case. If an iPad is not available, data can be recorded on paper (Appendix B) and later entered into the Geodatabase.

Navigating to the site

Surveyors use a GPS receiver to navigate the boat approximately 30.5 meters (100 feet) lakeward of the shoreline survey point that was generated in GIS. Each site extends 15 meters (50 feet) in either direction along shore from the GPS point for a total of 30.5 meters (100 feet) along shore (Figure 3-4). On developed lakes, survey sites are independent of lot ownership and often include portions of more than one lake lot. Photographing the site from a preset distance and the Collector for ArcGIS app can be used to help estimate the shoreline segment to be surveyed.

Figure 3-4. Score The Shore survey site



- Survey site extends 100 feet along shore: 50 feet on both sides of GPS point (yellow star).
- Survey site extends landward about 100 feet, or the setback distance for shoreland structures.
- Survey site extends lakeward about 50 feet and includes the area from shore to about the 5 feet depth where near-shore vegetation may occur.

Inaccessible sites

It may not be physically possible to motor within 100 feet of every site due to low water level, vegetation, navigational hazards, and/or recreational users. Surveyors may be able to view the site from an angle or from a distance greater than 100 feet and should record the GPS location of their viewpoint with a georeferenced photo. Note that the boundaries on the photo may include areas outside the actual survey site because it was taken at a distance greater than 100 feet. If the site cannot fully be viewed from the boat (example – located at end of long, narrow channel, at top of a steep bank), record as much information as feasible with an explanation that it was not entirely viewable by boat. Aerial photos may be used to help assess site conditions, but surveyors should note this in the comments field (example, “Shoreland Zone was not viewable from boat and was assessed from aerial photograph”).

Photographic reference

True photo-points are landscape photographs retaken each time from the same spot and filling the same frame so that landscape differences between years may be compared (Elzinga et al. 2001, Hall 2001). Score The Shore survey site photos document the site location and condition, but because they are taken from the boat and not a stationary, fixed location, they are not true photo-points. These photographs can be useful for quality control of data and to help monitor change in the type and amount of habitat within each lakeshore zone over time. The photographer's location likely changes slightly between years and the area included in each year's photo also changes; therefore, caution must be used when assessing the degree of change from photos alone.

The reference photo of the 100 feet shoreline survey site is taken from the boat, positioned approximately perpendicular from the center point of the survey site. For example, if using a Garmin Montana GPS camera, center the boat about 100 feet (30.5 meters) from shore to photograph the entire 100 feet segment of shore. When feasible, surveyors should try to survey sites and take photos with the sun at their back (early morning, later afternoon) and minimize sampling during poor visibility conditions (fog, heavy rain) or when sun can create dark shadows or harsh glare. Georeferenced photos are preferred but if this is not an option, surveyors should record the geographical coordinates at the site where the photograph was taken.

Assessing land use class

At each site surveyors determine the major land use class based on visual observation from the boat (example photos are provided in Appendix D). Aerial photography available on the Collector for ArcGIS app may be used to assist surveyors in their land use classification. Land use is assessed independently from land ownership. For example, survey sites within a State Park may be classified as developed (campsite, roadway, public park, boat access) or undeveloped and should not be classified as "Public Park" merely based on their presence within the State Park. Similarly, an undeveloped site may occur adjacent to a large agricultural field, but if the agricultural field does not extend into the survey site, the site should be classified as "undeveloped".

Surveyors first assess if any portion (Shoreland, Shoreline and/or Aquatic) of the site is developed and if so, the entire site is classified as developed.

Developed sites may or may not have building structures but do have some indication of human disturbance, such as removal of or cut vegetation, presence of a dock and/or structures on shore, and/or unnatural ground cover. Developed sites include eight classes:

- Single-Family Residential (one home within survey site)
- Several Single-Family Residential Lots (more than one home within survey site)
- Multi-Dwelling Development (e.g., apartment, condominium)
- Resort or Commercial Campground (typically multi-camper site)

- Other Commercial (e.g., restaurant, marina, hotel, school, etc.)
- Agricultural (pasture or cropland)
- Roadway
- Public Park (e.g., ball field, hiking trails, picnic area; without campground)
- Campsite (tent site or single camper)
- Boat Access (with or without parking lot and/or dock)

Only one development class is recorded for each developed site. If more than one type of development occurs at a site, select the class that occupies most of the site. For example, if a road runs through a site and there is a house on the landward side of the road, record the site as "roadway" because the majority of the (two-dimensional) site is occupied by the road. If the house occurs between the road and the lake, record the site as "single-family residential".

If no portion of the site shows signs of human disturbance, it is classified as undeveloped.

Undeveloped sites no portion of site shows signs of human disturbance and include two classes:
- Undeveloped Nonwetland (may or may not include trees)
- Undeveloped Wetland (may or may not include trees)

If an undeveloped site contains both nonwetland and wetland areas, select the class that occupies most of the site. Only sites where the Shoreland Zone is wetland should be listed as "Wetland." An undeveloped site that has a wetland Shoreline Zone but a nonwetland Shoreland Zone should be classed as "Undeveloped Nonwetland."

Shoreland Zone assessment

The Shoreland Zone is the portion of land which is most likely to be developed and approximates the required minimum setback distance for shoreland structures (Figure 3-4). The survey does not assess structures that may occur in the Shoreland or Shoreline Zones, such as boat houses, decks, staircases, and retaining walls. Depending on specific survey objectives, these types of data may be added to individual surveys. If a lake home and/or other buildings are present, surveyors can use the landward edge of the structures to determine the landward edge of the zone. The extent of the upland that can be viewed from a boat will vary with slope. Vegetation and structures may also limit the surveyors' view onto the land. Surveyors score three features in the Shoreland Zone:

1. **Trees or Wetland**: the percentage of the 100 feet length of shore that contains trees or wetland vegetation. This estimate does not include trees found in the Shoreline Zone.
2. **Shrubs or Wetland**: the percentage of the 100 feet length of shore that contains a mid-canopy layer of shrubs and/or tree saplings or wetland vegetation. This estimate is independent of the tree cover. There may be no trees present in the zone but a shrub layer may be present.
3. **Natural Ground Cover or Wetland**: the percentage of the 100 feet length of shore that is undisturbed and covered by natural ground cover, which may include:

    a. un-mowed vegetation, like grasses and wildflowers (note: surveyors are not asked to distinguish between native and non-native plants because this could require close inspection of individual plants and would require extensive botanical knowledge).
    b. tree leaves and needles, and mosses
    c. sand/rocks/bedrock that have not been placed by humans
- Unnatural and/or disturbed ground cover includes:
    a. mowed vegetation
    b. cultivated sites including horticultural and agricultural gardens
    c. areas covered by mulch
    d. areas covered by pavement, retaining wall or other placed impervious surfaces

Shoreline Zone assessment

The Shoreline Zone is the portion of land between the Shoreland and Aquatic Zones (Figure 3-4). It begins at the water's edge and extends landward to the bank. This zone may be narrow or broad, depending on the slope. Scoring the Shoreline Zone is similar to the Shoreland Zone assessment, but the tree layer and the shrub/sapling layer are combined and wetland vegetation may be present instead of terrestrial plants. Surveyors score three features in the Shoreline Zone:

4. **Trees/Shrub or Wetland**: the percentage of the 100 feet length of shore that contains trees and/or shrubs and/or wetlands.
5. **Natural Ground Cover or Wetland**: the percentage of the 100 feet length of shore that is undisturbed and covered by natural ground cover (as defined above for the Shoreland Zone) and/or wetlands.
6. **Overhead woody habitat**: presence of overhead woody habitat anywhere along the 100 feet of shore. This includes live or dead trees and/or shrub branches that extend over the water surface.

Aquatic Zone assessment

The Aquatic Zone begins at the land-water interface and extends lakeward 50 feet (Figure 3-4). It includes shallow water where rooted aquatic plants may grow; this is also the zone of a lake most likely to be utilized and impacted by riparian residents. The presence or absence of aquatic vegetation at a particular lake site can be influenced by a variety of natural and human factors and determining the relationship between development and current in-lake conditions can be challenging. Submerged vegetation can be difficult to observe visually if there is wave action and/or turbid water. The lakeward distance to which vegetation grows is dependent in part on depth, which varies considerably between sites and lakes. For these reasons surveyors assess only two dimensions of the aquatic zone: the length of the site (the 100 feet segment), and the layers of above-water vegetation (floating, emergent, overhanging vegetation). The third dimension – the lakeward distance to which vegetation extends, and the fourth dimension – the depth to which aquatic vegetation extends, are not assessed. Surveyors score three features in the Aquatic Zone:

7. **Openings in plant stands**: surveyors record whether any plant stands have any unnatural openings such as boat channels or other cleared areas around docks and swim beaches. Note that plant stands may have natural openings, and it can be difficult to determine the difference between natural and unnatural openings. Unnatural openings are most easily detected if they have sharp, rectangular edges (such as boat channels).
8. **Downed woody habitat**: surveyors record if downed woody habitat is observed anywhere in the Aquatic Zone. Downed woody habitat includes trees, limbs, branches, roots and wood fragments at least four inches in diameter (Ahrenstorff et al. 2009) that are entirely in the water as well as woody habitat that is partly on the shoreline.
9. **Number and types of docks**: surveyors record the number of in-water structures by type:
    a. Simple dock – a straight or L-shaped dock; no platforms or slips
    b. Complex dock – a dock that includes platforms and/or slips
    c. Lift – a device for elevating boat above water surface; typically attached to a dock
    d. Raft or other recreational objects – a platform that is anchored offshore and not connected to a dock; may be constructed of wood or other building materials or inflatable; and includes other recreational objects such as slides or trampolines
    e. Marina – a dock with numerous slips that is associated with a commercial facility or multi-dwelling residence
10. **Emergent and Floating-Leaf Vegetation**

Surveyors record the percent of the 100 feet of shore that contains emergent and floating-leaf plants. Surveyors don't need to measure or map these plant stands, but simply estimate the shoreline extent where these plants occur. The lakeward extent of these plant stands is not assessed because it will vary with water depth, substrate, fetch and other factors. This feature is not included in the site score.

Data management and analysis

Scoring system

For each of the nine features, a numeric point value is assigned based on the natural condition of that feature (Table 3-2). The number of points assigned to an individual feature may range from 0 to 20, with a maximum of 150 points per site. The total points are then converted to a score on a scale from 0 to 100. The maximum possible weighted score in each of the three Zones is 33.33 for a maximum possible site score of 100.

$$Final\ Weighted\ Site\ Score = \left(\frac{TotalPoints}{150}\right) * 100$$

Table 3-2. Scorable features for Score the Shore survey

Zone / Feature	Category	Points	Score
1. Shoreland -Percent of frontage with trees	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
2. Shoreland - Percent of frontage with shrubs	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
3. Shoreland - Percent of frontage with natural ground cover	75-100	10	6.67
	50-74	7.5	5.00
	25-49	5	3.33
	1-24	2.5	1.67
	0	0	0
4. Shoreline - Percent of frontage with Trees, Shrubs and/or Wetland	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
5. Shoreline - Percent of frontage with Natural Ground Cover or Wetland	75-100	20	13.33
	50-74	15	10.00
	25-49	10	6.67
	1-24	5	3.33
	0	0	0
6. Shoreline - Overhead Woody Habitat	yes	10	6.67
	no	0	0
	no	10	6.67

Table 3-3. Scorable features for Score the Shore survey (continued)

Zone / Feature	Category	Points	Score
7. Shoreline - Overhead Woody Habitat	yes	10	6.67
	no	0	0
8. Aquatic - Human made openings in plant beds	yes	20	13.33
	no	10	6.67
9. Aquatic - Downed woody habitat	yes	0	0
	no	0	0
9. Aquatic - In-water structures			
No docks, rafts, lifts, or marinas		20	13.33
1 simple dock		15	10.00
At least one simple or complex dock AND <3 lifts		10	6.67
At least one simple or complex dock AND >2 lifts		5	3.33
1 or more marina		0	0

Based on data collected through 2015, mean lakewide scores are interpreted as Excellent, Good, Fair or Poor and a similar rating interpretation is provided for each zone component (Table 3-3).

Table 3-4. Interpretation of Score The Shore survey data

Mean Lakewide Score	Mean Shoreland Score	Mean Shoreline Score	Mean Aquatic Score	Rating
85-100	28.0-33.3	28.0-33.3	28.0-33.3	High
66-84	22.0-27.0	22.0-27.0	22.0-27.0	Moderate
50-65	17.0-21.5	17.0-21.5	17.0-21.5	Low
<50	<17.0	<17	<17	Very Low

Quality control

In general, data observed and recorded on-site should be considered accurate. Although much of the habitat can be observed in photographs, surveyors at the site can better view and interpret the amount of habitat present. Features such as in-lake woody habitat cannot usually be detected on photographs.

Photo-points can be used as quality control checks, and they may be particularly useful for verifying surveys conducted by new student interns. For example, a new surveyor may misunderstand directions

on where to delineate the boundaries between zones and record Shoreline Zone trees as present in the Shoreland Zone. It is most helpful to try to detect these types of errors early in the season before the new surveyor conducts additional surveys. Photo-points may be most useful for verifying large amounts of change at survey sites between repeated survey years.

Data storage and analysis

Field data collected with Collector for ArcGIS app on an Ipad are synced to a geodatabase that is backed up on a network drive. Data collected on paper are manually added to this database (see directions in GIS Manual). Georeferenced photos are stored separately on a network drive.

Summary Score the Shore data are available on MNDNR GIS QuickLayers.

Example metrics that can be obtained from these data include:

1. Lakewide mean Habitat Score, ranging from 0 to 100
2. Lakewide mean score for each of the 3 habitat zones (Shoreland, Shoreline, Aquatic) ranging from 0 to 33.3
3. Mean Habitat Score for developed sites
4. Mean Habitat Score for undeveloped sites
5. Individual Site Habitat Scores

Chapter 4 Mapping Stands of Floating-leaf and Emergent Plants

Objectives

1. Delineate, classify and digitize boundaries of shallow water plant stands in lakes
2. Collect additional information on the geographic locations, size (boundaries) and floristic composition of plant stands to further refine classification and management
3. Detect a 10% change in the lakewide quantity of emergent and floating-leaf plant communities

Introduction

Classifying and mapping vegetation is critical for natural resource planning, management and protection. A map can provide a physical delineation of plant growth occurrence in a lake. By classifying vegetation, selected properties of the plants can be used to describe and differentiate areas of plant growth. The tasks of mapping and classifying plant communities are intimately related – the purpose of the map determines the classification used and the choice of a classification strongly affects the map (Kuchler 1951). For example, if the map purpose is to locate areas of emergent plant growth, the classification must distinguish taxa by life form, but species level identification may not be required.

MNDNR Native Plant Community (NPC) classification system focuses on terrestrial and palustrine systems (Aaseng et al. 2011). This ecologically based classification system was developed from detailed (species level identification) vegetation relevé plot data collected across the state. Ecologists and other resource managers use field guides (MNDNR 2003) developed from this classification to categorize plant communities at several scales.

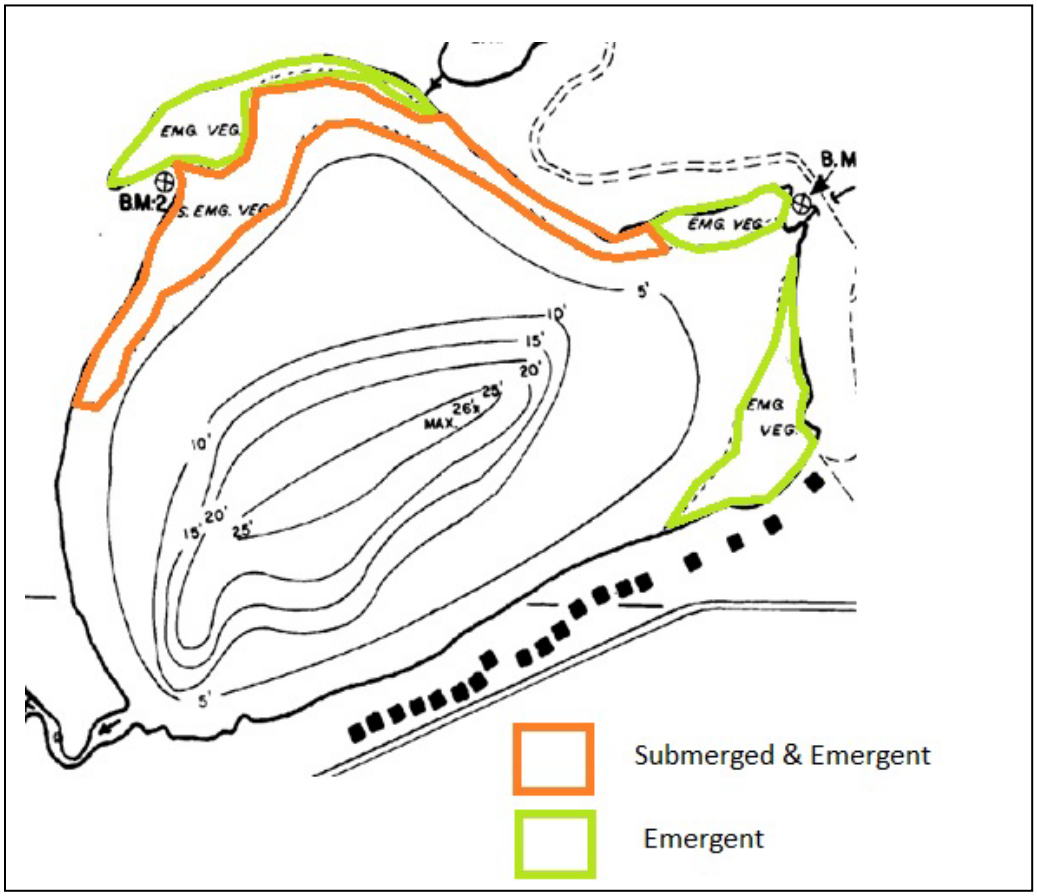
Because detailed relevé plot data are lacking for lakes, lacustrine plant communities were not classified in MNDNR's NPC Classification System. This created a gap for resource managers. Sites of high quality terrestrial and/or wetland native plant communities have been identified and mapped throughout the state, but a substantial quantity of aquatic habitat remains un-mapped. This is particularly problematic for landscape-scale planning where terrestrial and aquatic habitat should be considered together.

There are multiple needs for data on aquatic plant stands. Maps and descriptions of aquatic plant stands are required to support a variety of resource assessment, management and conservation goals. MNDNR Fisheries needs information on current locations and extent of bulrush (*Schoenoplectus* spp.) stands and unique aquatic plants that should be protected from most plant control activities. MNDNR Wildlife, MPCA and Tribal Nations want to document the occurrence and dynamics of wild rice stands (*Zizania*

spp.), which includes information on stand size and composition (monotypic vs. mixed with perennials). MNDNR Aquatic Invasive Species Program, lake groups and local units of government are interested in mapping non-native species, documenting potential spread and monitoring impacts of control activities. MNDNR Natural Heritage Program records boundaries of rare plant stands.

Historically, Minnesota lake surveyors mapped lake plant stands by hand drawing the estimated perimeter of plant stands on lake depth contour maps and recording taxa observed, often to the species level (MNDNR 1993). While these types of data are different than the relevé plot-based data used for MNDNR's NPC classification, they can be used to classify each stand into one of three broad life form categories (emergent, floating-leaf or submerged) (Figure 4-1).

Figure 4-1 Historical hand-drawn map of emergent and submerged vegetation stands



In 2005, MNDNR Fisheries and Ecological Services biologists revised lake plant mapping protocols and incorporated GPS data collection and GIS mapping (MNDNR 2005). These new protocols included a combination of aerial photography interpretation and field surveys. Field survey methods included delineation of plant stand boundaries with GPS, identification of canopy dominant taxa, estimates of overall plant cover, and estimate of species cover. This effort built on earlier work, incorporated lessons

learned from the past decade of GPS mapping conducted by MNDNR biologists and included new options available through recent advancements in GPS technology and GIS software.

In a protocol repeatability study, Radomski et al. (2011) demonstrated that coverage mapping of emergent plant stands can be completed in a timely manner and with reasonable precision. For example, in lakes with monospecific bulrush stands, it may be reasonable to detect a whole lake change of 10% or greater using the techniques described in this manual.

In this manual, we consider the increasing advances in GPS technology and GIS software that now allow more efficient georeferenced vegetation delineation. We re-evaluated the process for classifying lake plant communities and developed a method that meets the primary needs of resource managers within the constraints of the available data types. Provided here is a hierarchical approach for mapping aquatic vegetation designed to meet the specific needs of individual aquatic vegetation surveys that can also be integrated into broader Departmental planning processes.

Definitions

Vegetation: a generic term used to describe the collective plant cover of an area.

Stand: an area of vegetation that is identified based on distinctiveness and uniformity.

Class: a group of individuals or other units similar in selected properties and distinguished from all other classes of the same population by differences in these properties (Buol et al. 1973). Plant classes may be defined based on shared physiognomic and/or floristic characteristics that distinguish them from other kinds of plant communities or vegetation. In lakes, vegetation classes may be based on shared growth forms and be reflective of patterns of water depth, substrate, water clarity, water chemistry and disturbances.

Classification: the process of grouping similar entities together into named classes based on shared characteristics. Vegetation classifications are typically hierarchical with varying levels of detail available to map. Classification systems can be organized using a dichotomous key.

Ecological classification: a classification in which numerous differentiating criteria are selected to highlight relationships of the most important properties of the population being classified without reference to any single specified and applied objective; vegetation types are based on assemblages of plant species that co-occur in an area and are linked by their interactions with each other and their environment (Whittaker 1978).

Dominance-type classification: A classification based on the dominant taxon or taxa. Classifying by dominance-type requires a basic understanding of plant communities (Jennings et al. 2004). In this context it is “a recurring plant community defined by the dominance of one or more species which are usually the most important ones in the uppermost or dominant layer of the community” (Gabriel and

Talbot 1984 as cited in Jennings et al. 2004). This manual uses a dominance-type classification with the following levels:

- **Life Form**: the highest and broadest level in which plant stands are classified. Life Form is useful at the statewide and/or regional mapping scale. There are three life forms: Emergent, Floating-leaf, and Submerged.
- **Class**: the intermediate level where plant stands are primarily classified by dominant taxa.
- **Primary-Secondary Taxa Group**: the lowest and finest-scale classification level where plant identification to the species level or species complex level may be feasible and useful.
- **Associated Taxa**: taxa that are observed in the plant stand but that do not dominate.

Aquatic plant stand classification system

This aquatic plant classification system is a dominance-type classification (Whittaker 1978) based on collective field experience of MNDNR biologists, existing descriptive data and a review of lake plant studies. This classification was developed mainly for use in documenting the location, size and floristic composition of lake plant communities. Broad units of classification (e.g., wild rice) can be used to guide management of the largest and most frequently occurring community types. Lower units of classification may be used for local or regional management planning, to identify community types in need of conservation, and to gain knowledge about less frequently occurring taxa associations. Compilation of associated taxa within mapped polygons may be used to document geographical range and extent of individual taxa (e.g., which mapped polygons contain *Equisetum*, (horsetail)) and possibly to further refine this classification.

This classification system is a three-level hierarchical design (Table 4-1) permitting a gradation of refinement appropriate for most lake plant GIS cover mapping projects. Plant stands are assigned to groups within a system of categories distinguished primarily by life form, dominant taxa, and the ability of surveyors to recognize groups in the field and/or by remote sensing.

Table 4-1. Three levels of Minnesota's Aquatic Plant Stand Classification

Classification Level	Dominant Factors	Example
Life Form	Physical height of plant with respect to water level	Emergent
Class	Canopy dominants with options restricted to rushes, wild rice, cattail, or waterlilies and all other taxa are grouped as “other”	Rushes
Primary-Secondary Taxa Group	Finer distinctions in canopy dominants	Three-square bulrush (*Schoenoplectus pungens*)

Life Form is the highest and broadest level where plant stands are classified and is useful at the statewide and/or regional mapping scale. There are three life forms: Emergent, Floating-leaf, and Submerged. This level has been used by surveyors since the 1940s to delineate major stands of vegetation in lakes. It is also the level at which most field staff can conduct aerial photointerpretation of stands from readily available photos and without having extensive photo-interpretation experience (e.g., while it is possible to distinguish burreed (*Sparganium*) from cattails (*Typha*) on some aerial photos, without ground-truthing most field staff may only be able to identify "emergent" vegetation).

Class is the intermediate level where plant stands are primarily divided by dominant taxa. We have identified 11 Lake Plant Classes which represent the main types of aquatic plant stands in Minnesota. The Class level may be useful for mapping at the lakewide and/or watershed scale. These are groupings that can be readily recognized by field biologists who are not trained as botanists. These classes are large enough (acreage-wise) that it makes sense to display them at a regional, multi-lake scale.

The 11 Lake Plant Classes (Table 4-2) attempt to place plant stands into groups that have ecological meaning. Structurally heterogeneous stands are distinguished from monotypes because different canopy layers and types provide different microhabitats (example: presence of floating-leaf plants creates shade; leafy emergents provide above water surface area for invertebrates). Temporal variation in stands is also distinguished. For example, stems of bulrush and cattails typically persist throughout the winter while waterlilies, wild rice, and other emergents disintegrate. Finally, physical habitat variation in stands is distinguished. For example, wild rice, waterlilies and many broad-leaf emergents are often associated with soft-sediments and protected bays while bulrush are associated with hard substrates and once established, can withstand more fetch.

Primary-Secondary Taxa Group is the lowest and finest-scale level where plant identification to the species level or species complex level Fig be feasible and useful. Plant stands identified at this level may represent regionally important types of plant stands [e.g., watershield (*Brasenia schreberi*)] or minor components of the statewide aquatic plant communities (i.e., generally small stands that if mapped would not show up on a multi-lake level map). These groups have important ecological significance, and more data may be required for better understanding their distribution and function (e.g., three square bulrush (*Schoenoplectus pungens*) distribution may be strongly influenced by ice scour; yellow waterlily (*Nuphar variegata*) may grow in deeper water than white waterlily (*Nymphaea odorata*); the presence of certain broadleaf emergents in bulrush stands may signal that the substrate type is shifting to more organic). The primary taxon is the most dominant taxa in the stand. If a second taxon is also frequent (occurring in at least 30% of the stand), but not the dominant taxon, it may be listed as the secondary taxon. A secondary taxon is not required and only one secondary taxon can be listed.

Associated Taxa are recorded in each stand. These taxa are not the primary or secondary dominant taxa and typically occur in less than 30% of the stand. By recording these taxa, we retain the ability to identify stands that contain specific taxa (e.g., identify all plant stands where horsetail (*Equisetum*) was observed).

Table 4-2. Minnesota Aquatic Plant Stand Classification based on Life Form and Dominant Taxa

Class	Dominant Taxa	Secondary Taxa
1. Cattail	***Typha* spp.** *Typha* sp. (cattail genus) *Typha angustifolia* (narrow-leaf cattail) *Typha x glauca* (hybrid cattail) *Typha latifolia* (broad-leaf cattail)	None or other cattails
2. Cattail and Other	***Typha* spp.** *Typha* sp. (cattail genus) *Typha angustifolia* (narrow-leaf cattail) *Typha x glauca* (hybrid cattail) *Typha latifolia* (broad-leaf cattail)	Leafy (non-Cattail) emergent plants and /or floating-leaf plants
3. Rushes	***Schoenoplectus* spp.** (bulrush genus) *S. acutus* (hardstem bulrush) *S. tabernaemontani (*softstem bulrush) *S. pungens (*three-square) *Bolboschoenus fluviatile* (river bulrush) ***Eleocharis* spp.** (spikerush genus) *Eleocharis palustris* (marsh spikerush)	None or other Rushes
4. **Rushes & Other**	***Eleocharis* spp.** (spikerush genus) *Eleocharis palustris* (marsh spikerush)	None or various – This Class includes homogenous and heterogeneous stands
5. **Wild Rice**	***Zizania palustris*** (manoomin, wild rice)	
6. **Wild Rice & Other**	***Zizania palustris*** (manoomin, wild rice)	None or various – This Class includes homogenous and heterogeneous stands
7. Other Emergents	**Other Emergent Examples include:** *Equisetum fluviatile* (horsetail) *Phragmites australis (*common reed grass) *Sparganium* spp. (emergent bur reed) *Sagittaria* spp. (arrowhead)	None or various – This Class includes homogenous and heterogeneous stands
8. Waterlilies	***Waterlilies (Nymphaeaceae)*** *Nuphar variegata (*yellow waterlily) *Nymphaea odorata* (white waterlily)	
9. Waterlilies and Others	***Waterlilies (Nymphaeaceae)*** *Nuphar variegata (*yellow waterlily) *Nymphaea odorata* (white waterlily)	None or various – This Class includes homogenous and heterogeneous stands
10. Other Floating-leaved	**Other Floating-leaf taxa** *Brasenia schreberi* (watershield) *Persicaria amphibia* (smartweed) *Potamogeton natans* (floating-leaf pondweed) *Sparganium* spp. (floating-leaf bur reed)	None or various – This Class includes homogenous and heterogeneous stands
11. Submerged	**Submerged** Examples may include: Rare or unique submerged species that are visible from water surface (ex*. Potamogeton vaseyi, Hippuris vulgaris*)	None or various – This Class includes homogenous and heterogeneous stands

Since plant abundance measures are not a component of this survey, this protocol minimizes cognitive burdens to the surveyor while conducting the survey. Having to determine relative abundance is difficult, especially across the full extent of a stand, and such subjective abundance estimates are often not repeatable. If the surveyor determines that an area includes a distinct aquatic plant stand of sufficient size, then the stand is delineated and mapped.

This is not an ecological classification developed to incorporate abiotic attributes such as water depth, water chemistry (e.g., alkalinity), substrate nutrients, flooding regimes, and biological attributes (e.g., associations of plant taxa). An ecological classification has been done for non-aquatic plant communities in Minnesota where relevé plot vegetation and soils data form the basis for classifying plant communities (Aaseng et al. 2011).

Survey Design

Protocols include a combination of aerial photo interpretation and delineation with field-truthing, and field delineation and classification. Only large stands of emergent and floating-leaf vegetation are mapped, as mapping of small stands is resource intensive and imprecise using available GIS tools. Minimum mapping area is about the size of a pontoon boat (>10 m^2). Plant stands are characterized by life form, plant class, the dominant genera or species, and associated species or taxa.

While the Submerged life form is included in this classification system, surveyors should focus on Emergent and Floating-leaf life forms. The ability to visually observe the boundaries of submerged stands vary with water clarity, depth, wind, plant height and plant cover. Types of submerged plant stands that may be most suitable to delineation include matted submerged plant areas, submerged plants that form floating-leaves, and unique shallow water plant stands growing in clear water. IMPORTANT: If surveyors elect to map submerged stands, the polygons cannot overlap with emergent or floating-leaf stand polygons.

Pre-survey preparation

Training

LEU staff provide training on aquatic plant stand classification and field mapping techniques. Training helps ensure that all surveyors are recording similar information when they observe plant stands. The most difficult types of stands to classify are those that have multiple species and it is useful for surveyors to observe these stands together and discuss appropriate classifications prior to mapping.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix A. The preferred method of data collection is with the Collector for ArcGIS App. For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual).

Conducting the survey

Aerial photo delineation

If recent aerial photos are available, they may be used to map some types of emergent, floating-leaf, and matted stands of submerged plants. Detection and identification of plants is influenced by water depth, plant cover, plant condition and image date, quality and type. Remote sensing, with photography or other imagery, can be useful for sites where land ownership and/or navigation issues prevent staff from conducting field assessments. For extensively large sites, remote sensing may be more cost and time effective than field surveys. It also provides the option to assess historical vegetation if imagery is available (Xie et al. 2008).

Some issues associated with aerial photo delineation include difficulties identifying dominant taxa within stands or failure to even detect vegetation stands. The first issue can be improved by experience and training of staff. The second issue may occur if plant stands are small and/or were not visible on the photos (example: narrow stands of plants that occur near the shore may be blocked from view by overhanging shoreline trees). There may also be situations where only a portion of the actual stand appears on the photo; examples of this include stands where plant cover is not uniform throughout the stand and the sparsely vegetated portions of the stand do not appear on the photo.

If aerial photos are used, document the photo source, scale, and date. Use photos that have been rectified and realize that the locations on the photo are only as accurate as the photo rectification. Use several photo sources, if possible, because different types of vegetation may appear different on separate photos. Spring, “leaf-off”, black and white photos can be helpful in distinguishing cattail stands from ephemeral vegetation. Aerial photo delineated maps often require field-checking to determine or verify species compositions of stands. Changes in vegetation observed between different photo dates can also be confirmed.

Field delineation

Plant stands that cover more than 10 m^2 (about the area covered by a pontoon boat) can be delineated in the field. Surveyors may use field mapping to delineate all the emergent and floating-leaf plant stands or they may elect to focus on emergent and floating-leaf vegetation stands that may be difficult to see on aerial photos. Special project objectives may dictate mapping only selected stands, such as rare or non-native species locations.

If surveyors are not familiar with the lake, a review of aerial photos and any existing plant survey data, along with a reconnaissance survey, can help estimate the extent of vegetation to be mapped. Field surveys are generally conducted during mid to late summer during the peak of plant growth and before non-persistent plants die back. There may be specific seasonal requirements for mapping some taxa; for example, the submerged plant, curly-leaf pondweed, must be delineated in the spring or early summer

because it dies back around early July. Surveys are done under low to moderate wind conditions (< 20 km/hr). Shallow sites may be mapped on foot by wading along the plant stand perimeter while deeper sites are conducted by boat. A boat less than 5.8 m length, with console steering and/or a trolling motor, is easiest to maneuver around plant stand perimeters.

Habitat is mapped and digitized using GPS and GIS. Because surveys often include a combination of boat work and wading, a hand-held GPS unit is appropriate. These devices can be temporarily mounted on the boat console and easily removed for use while wading. GPS units are set to automatically collect location data at a minimum one-second interval. Position accuracy of the Garmin unit is typically less than 10 meters (Garmin 2006). In emergent mapping tests, estimated position error for the Garmin units averaged about three meters during surveys (Radomski et al. 2011).

Mapping with ESRI App and Garmin Glo unit

ArcGIS Field Maps is a mobile GIS application developed for collecting spatial data in the field. This app coupled with an iPad and Garmin GLO GPS unit, may be used to map and classify plant stands in the field. Information on the plant class and associated taxa are selected and recorded within a geodatabase at the time of field delineation. This approach increases consistency, reduces data entry errors and reduces time required to process field-collected data. The collected data are then automatically integrated with a centralized geodatabase.

Mapping with hand-held GPS unit

Hand-held units that have been used successfully to date include Trimble GeoExplorer and Garmin units (Map 76 series, Montana). Trimble units allow surveyors to record the plant class that is associated with each mapped polygon. Most MNDNR staff have Garmin units which do not provide this option. If mapping with a hand-held GPS unit and more than one plant class is mapped, surveyors must collect a series of waypoints, track and notes to identify the plant class associated within each polygon. Post-processing must occur back in the office to create polygons from the tracks and then to assign a plant class to each polygon.

Field classification

At the time of delineation, each aquatic plant stand is classified into one of 11 classes (Table 4-3) by identifying 1) the dominant life form (emergent, floating, or submerged), 2) the dominant plant taxon, and 3) the presence or absence of a secondary dominant taxon. For emergent and floating-leaf plant stands, any additional emergent or floating-leaf plant taxa observed are recorded. A dichotomous key to the 11 Lake Plant Classes is provided in Appendix D.

No overlapping stands are delineated [e.g., if bulrush stands grade into waterlily stands, surveyors must decide on a boundary to separate the stands (Figure 4-2, Figure 4-3)]. If it is not physically feasible to navigate between the two stands without destroying vegetation, an aerial photo may be used to help

place the boundary line. In extensive plant stands, surveyors may not be able to physically view the entire stand to confirm plant community uniformity. Aerial photos may be useful to help determine if portions of the stand should be subdivided into separate plant classes.

Figure 4-2 Example delineations of Floating-leaf and Emergent plant stands

A) Waterlily plants occupy area below the minimum mapping area ($10m^2$) (about the area of a pontoon boat)
B) Wild rice stands are bisected by docks and can be mapped as three polygons in the field or as one polygon that is subdivided later (see inset E)
C) Waterlily stand occurs adjacent to D
D) Cattail stand but they are delineated separately. This can either be done in the field by motoring between the plants or in the office using aerial photos.
E) Wild rice stands subdivided by docks

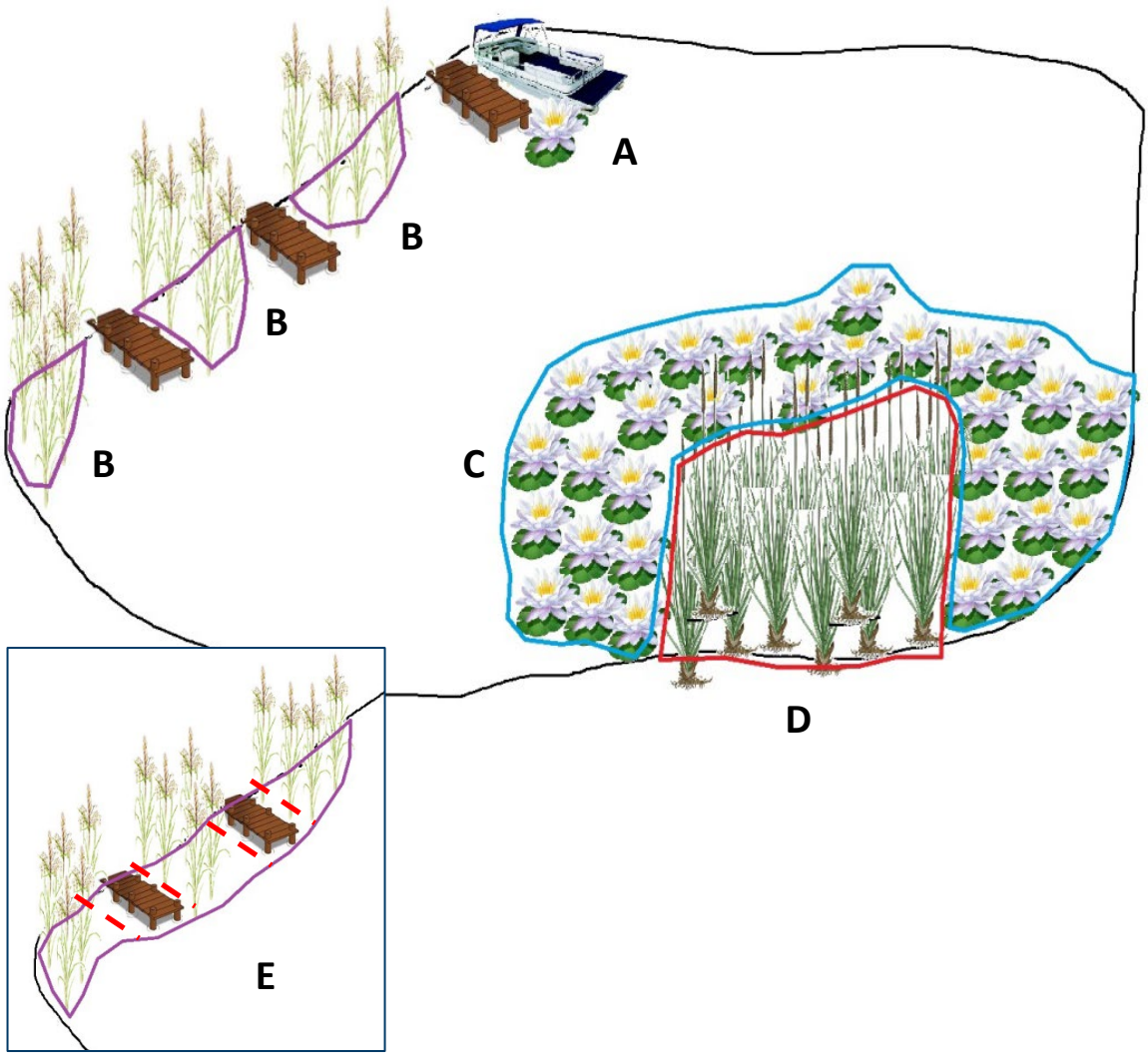
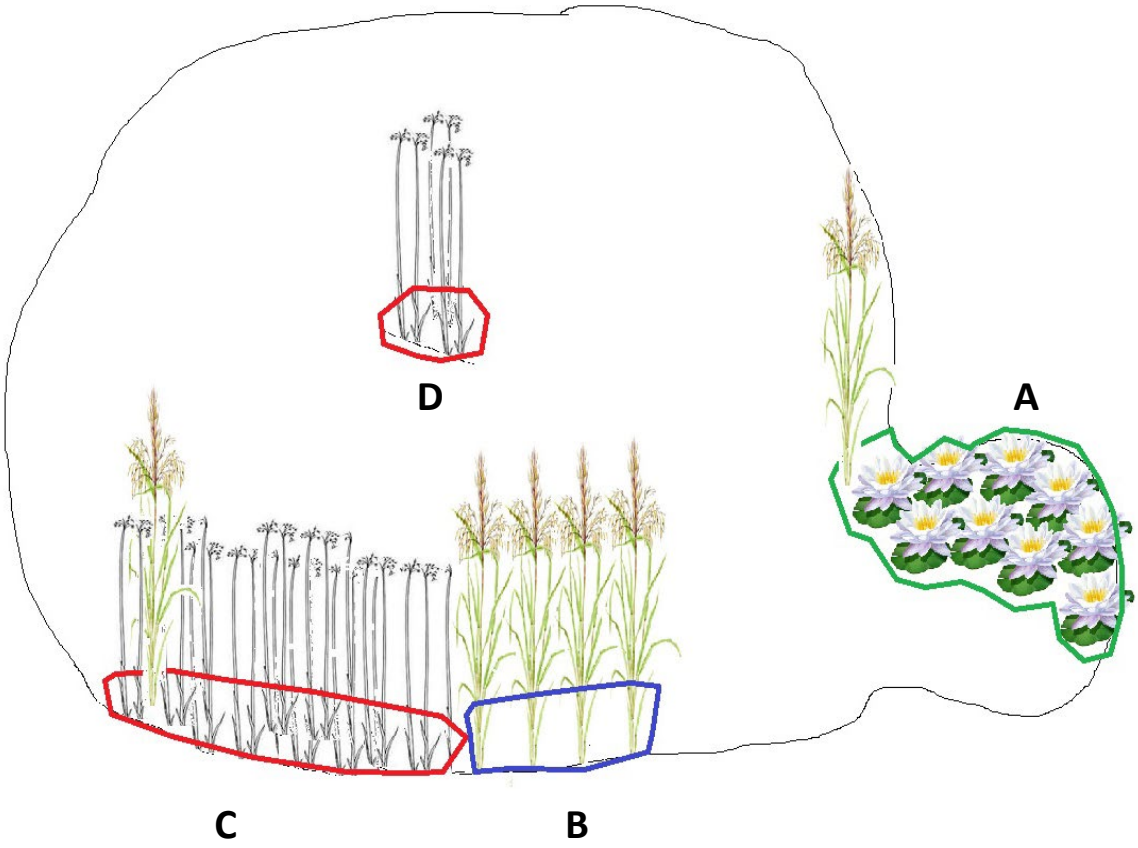


Figure 4-3 Example delineations of aquatic plant stands

A) Class = Waterlily (Individual plant of wild rice is included in polygon but because of low abundance it does not change the Class)
B) Class = Wild Rice
C) Class = Bulrush (Individual plant of wild rice is included in polygon but because of low abundance it does not change the Class)
D) Offshore stand; Class = Bulrush



Data management and analyses

Post-processing of field GIS data

The amount and type of post-processing data management depends on the field method used to delineate plant stands.

GIS data collected with ArcGIS Field Maps
This is the preferred method for delineating and classifying plant stands because it enforces a standardized classification system and improves efficiency by reducing GIS processing back at the office.

GIS data collected with hand-held GPS
Data collected using hand-held GPS can be imported to the statewide geodatabase but require more extensive post-processing. This method is not recommended, particularly if there is more than one plant class on a lake and/or if plant stands are not monotypic. GPS data are imported into a GIS for processing. GPS track lines are edited to create stand polygons. This is accomplished by snapping near-shore plant stand track lines to the land/lake boundary layer and by connecting track lines of offshore stands. This means that surveyors need to make a small data processing decision for nearly every stand. In addition, lake plant class, primary-secondary taxa, and associated taxa from field notes must be assigned to each created stand polygon.

Data storage and analysis

Field data collected with Collector for ArcGIS app on an Ipad are synced to a geodatabase that is backed up on a network drive. Data collected on paper are manually added to this database (see directions in GIS Manual). Georeferenced photos are stored separately on a network drive.

After polygons for each mapped vegetation stand are created and classified, whole-lake estimates of plant stand coverage are determined by plant class. The percent of shoreline with adjacent plant stands can also be estimated.

Floating and emergent lake plant stand data are available on MNDNR GIS QuickLayers.

Chapter 5 Lakewide Plant Taxa Inventory - Transect Survey

Objectives

The protocol within this chapter is designed to structure the collection of a lake plant taxa list to obtain standardized taxa richness data.

Introduction

Taxa richness, or the estimated number of taxa in a community, is the oldest, most fundamental, and perhaps least ambiguous concept of diversity. This metric can be a useful tool to describe and compare aquatic plant communities and may also reflect and detect changes in water quality conditions. The term “richness” is often used instead of “taxa number” to emphasize that the actual number of species or taxa in a community may be difficult or impossible to determine. Any estimate of number of species or taxa is dependent on sample size; the larger the sample size the greater the expected number of species, (i.e., as more individuals are sampled, more species will be recorded).

MNDNR Fisheries began using the transect vegetation survey in 1993. It was designed before GPS was readily available for field survey work and provided a method to systematically survey lake vegetation in a relatively rapid manner. It was adopted from a method (Jesson and Lound 1962) where transects are established perpendicular to shore at equal distances around the lakeshore. In the Jesson and Lound method, surveyors sample at predetermined depth intervals or at distance intervals along the transect; the boat is anchored at each site and four subsamples are collected with a rake sampler. To minimize sampling time, the 1993 Transect Survey eliminated the sample stations along the transect, making the survey area the entire area of the transect. It is a highly effective way to collect a species list because a relatively large portion of the lake is included in the survey area. However, because the individual sample stations were eliminated and the individual survey area is very large, this method is less effective at estimating plant abundance in a repeatable, quantitative manner.

Survey design

Transect number and spacing

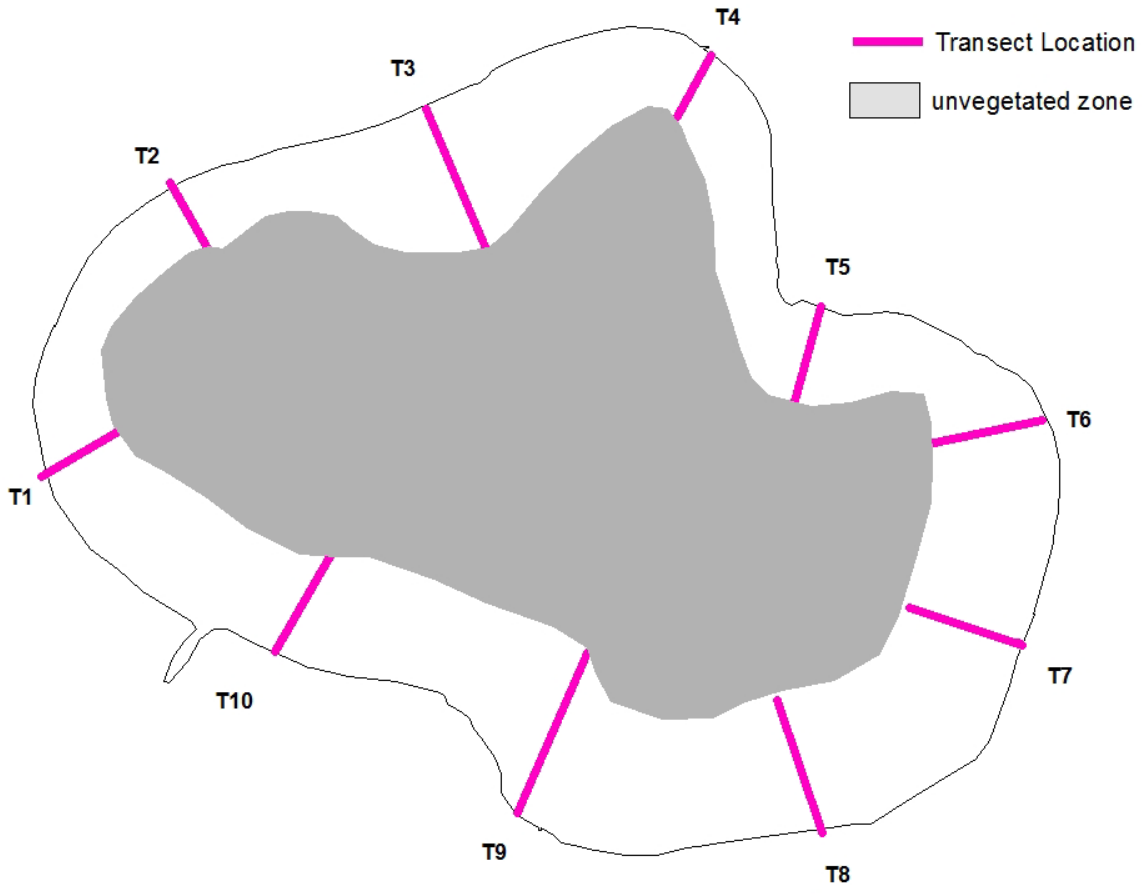
The number of transects is determined by lake size (Table 5-1) and transects are spaced at equal distances around the lakeshore (Figure 5-1). If a transect survey has been previously conducted on a

Table 5-1. Determining number of vegetation transects by lake area

Lake Size (acres)	Number of vegetation transects
<150	10
150-500	20
501-1000	30
1001-5000	40
>5000	50

Source: MNDNR 1993 Fisheries Lake Survey Manual

Figure 5-1 Placement of transects at equal intervals around lakeshore



lake, then surveyors should use the original transect locations. Transects run perpendicular from shore to the maximum depth of vegetation growth. If vegetation extends all the way across the lake, transects will end at the halfway point, or at the maximum depth in which plants are growing if the distance across the lake is substantial.

Transect length and area

The length of each transect is not standard and will vary within and between lakes because it is determined by the maximum depth at which vegetation is detected. Each transect is about 25 feet in width and includes about 10 feet on either side of the boat as well as the area under the boat. Because the survey includes a combination of visual observations and rake sampling, the actual area of each transect that is sampled will vary with water clarity and depth.

Pre-survey preparation

Training

LEU provides annual training on aquatic plant identification.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data are entered electronically (e.g., Fisheries Lake Survey database interface) or recorded on paper forms (Appendix C).

On lakes where transect surveys have previously been conducted, GPS coordinates may be available for the shoreward and lakeward ends of each transect. For other lakes, transect locations will need to be created in GIS and surveyors will upload coordinates to a GPS unit.

Conducting the survey

Surveyors begin at the shoreward end of the transect and navigate to the lakeward end. A depth finder may be useful to help determine the maximum depth at which vegetation occurs. Surveyors use a combination of visual observations and rake sampling to detect vegetation within the transect area. To help standardize sampling, it is recommended that a rake toss sample be taken at every 5 feet depth interval along the transect. All vegetation observed and collected along the transect is identified to the lowest taxonomic level possible (often to the species level) and recorded as “present” on that transect. Surveyors also record the dominant substrate (Table 5-2) that was observed at the shallow end of the transect (< 4 feet water depth). In addition to the transect sampling, all other plant species observed should be recorded as present in the lake.

Table 5-2 Shoal substrate descriptions and codes

Substrate Group	Code	Type	Description
Ledge Rock	LR	hard	Large mass of solid rock
Boulder	BO	hard	Diameter over 10 inches
Rubble	RU	hard	Diameter 3 to 10 inches
Gravel	GR	hard	Diameter 1/8 to 3 inches
Sand	SA	hard	Diameter less than 1/8 inch
Sand/Silt	SS	hard	Sand bottom overlaid with thin layer of silt
Silt	SI	soft	Fine material with little grittiness
Clay	CL	soft	Compact, sticky material
Marl	MR	soft	Calcareous material
Muck	MU	soft	Decomposed organic material
Detritis	DE	soft	Organic material (leaves, twigs, etc.)

Adapted from: MNDNR 1993 Fisheries Lake Survey Manual

Data management and analysis

Surveyors enter data into Program-specific databases (for Fisheries this is the Lake Survey Module). Data are used to estimate lakewide plant taxa richness (the total number of taxa observed) and can be used to calculate floristic quality.

Chapter 6 Quantitative Lakewide Point-Intercept Survey

Objectives

The lakewide point intercept survey is designed to assess the distribution of plants on a lakewide or bay-wide scale. Because it is conducted by boat, this survey is most appropriate on lakes where most of the littoral zone can be accessed by boat. Frequency of occurrence is the metric used to estimate abundance. This survey is designed to, with moderate effort, assess changes in frequently occurring taxa and an extensive effort with a large number of sample sites is required to statistically assess infrequently occurring taxa. Primary goals include:

1. Describe the geographical distribution of plants throughout the littoral zone and within specific depth zone intervals.
2. Estimate the percent of the littoral zone that contains vegetation and be 95% confident that frequency estimates are within +/-20% of the estimated true value.
3. Estimate the abundance of frequently occurring taxa (those occurring in 30% or more of the vegetated zone) and be 95% confident that frequency estimates are within +/-20% of the estimated true value.

NOTE: It is not appropriate to use results of point intercept surveys to delineate sites for aquatic plant management. The mere presence of a plant at one site does not infer anything about the distribution or abundance of that plant in the area between survey sites.

Introduction

The traditional point-intercept survey is a plotless vegetation survey method used when delineation of a survey area is not possible or not desired. It is a method originally designed for grassland surveys. Surveyors establish a network of sampling points and use a frame of descending pins to record the plant species or ground cover classes that contact each pin (Goodall 1952, Kershaw 1966, Greig-Smith 1983). Plant frequency is estimated by determining the proportion of survey points that “hit” or intercept vegetation. Because the pinpoint is theoretically dimensionless, the frequency of contacts can be considered equivalent to percent cover. Surveyors view the plant community from above and the method is best suited for vegetation types less than one meter in height (Caratti 2006) with single canopies, such as grasslands. Park (1972) discusses modifications for assessing multiple canopy layers.

Terrestrial point-intercept surveys are often non-destructive because surveyors visually record observations without removing vegetation. For aquatic vegetation, particularly in water depths greater

than one meter, harvesting samples from a boat with a rake is more rapid and less costly than visual observation by SCUBA. Physical sampling may be minimally destructive because aquatic plants typically regenerate by fragmentation, rake harvesting does not often remove the entire plant, and repeat surveys are usually near, but not at, the original site. Nevertheless, physical disturbance to the plants is a factor to be considered when establishing long-term monitoring programs.

Madsen (1999) adapted the point-intercept method for lakes and established sample points across a grid pattern in the littoral zone; surveyors most often work from a boat using long-handled rakes or grapple hooks to sample vegetation. Using Madsen's modifications, the method is not "plotless" but rather incorporates a series of small plots approximately about one meter squared in size (the approximate lake bottom area covered by the rake grab). Because of this, it is most appropriate to estimate frequency of occurrence rather than true cover. If frequency is used as a proxy for coverage, such estimates are dependent on the resolution of the survey (Williams et al. 2008, Figure 6-1) and accuracy varies by species (Figure 6-2).

Figure 6-1 Usefulness of frequency data as proxy for cover is scale dependent

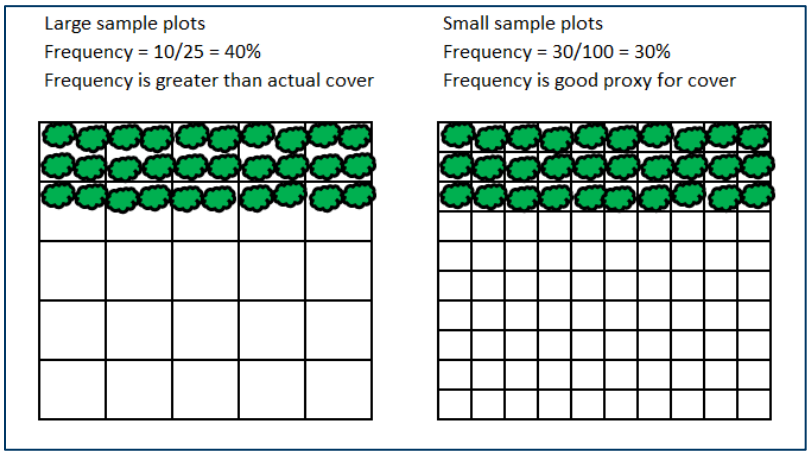
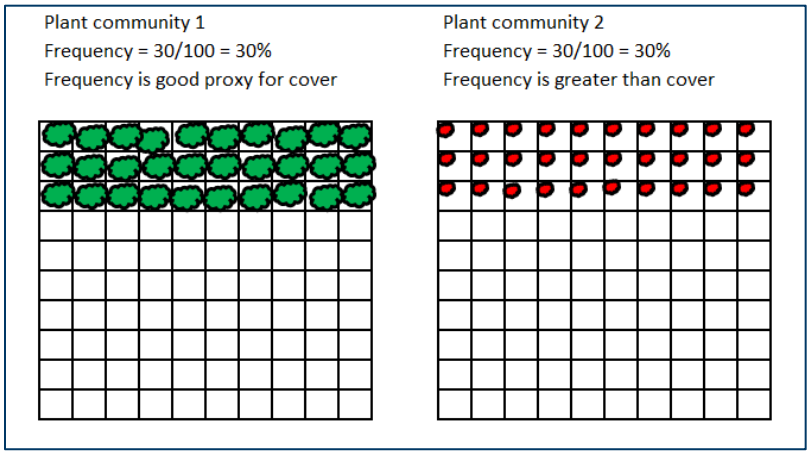


Figure 6-2 Usefulness of frequency data as proxy for cover is species and life-form dependent



In comparisons of several boat-based aquatic vegetation survey methods, the grid point-intercept method was found to provide the most rapid, repeatable, GIS-based method to assess lakewide plant species abundance and associated depth data (Perleberg 2001a, Perleberg 2001b). Other boat-based methods (Jesson and Lound 1962, Yin et al. 2000) provide more site-specific detail, but require the boat to be anchored at each sample site, thus reducing the total number of sites that can be sampled per hour. Point-intercept method advantages include consistency in data collection between different surveyors, ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). Williams et al. (2008) recommended the point-intercept survey for whole-lake assessments where statistical comparisons are needed. The technique has been extensively used by MNDNR for quantitative lake vegetation surveys conducted by EWR Division, Wildlife Shallow Lakes Program, and Fisheries Sentinel Lakes Long Term Monitoring Program. This method has also been adopted by the Wisconsin DNR as their standard lake vegetation survey method (Hauxwell et al. 2010).

Important reminders

After reviewing point intercept data collected by numerous surveyors, we have identified common survey design and/or data collection errors that should be avoided. These are discussed in detail in this chapter and highlighted here:

- A minimum of 225 sample sites per lake is recommended with:
    - A minimum of 75 points in the 0 to 5 feet depth zone
    - A minimum of 75 points in the 6 to 10 feet zone
    - A minimum of 50 points in each deeper strata
- Sampling should extend to water depths of 20 feet on most lakes.
- The maximum depth consistently sampled should be recorded.
- Stratifying sample sites by water depth helps ensure adequate sampling within each depth zones of interest.
- To avoid bias in sampling, surveyors should not move or add survey sites in the field and should not increase the individual sample site area (limit sampling to one rake toss and a visual observation of approximately $1m^2$).
- It is critical to distinguish between a site that was not sampled and a site that was sampled but where no vegetation was detected.
- If a depth zone is targeted for sampling, all sites are sampled regardless of whether vegetation is detected.

Survey design

Defining the survey area

The survey area should include the area of the lake where information on aquatic vegetation is needed. This may include areas that may not be vegetated during the current survey year but were vegetated in past years or where it is anticipated that they will be vegetated in future years. This is particularly important if the survey objective is to compare data between survey years. In most lakes the survey area will include all water depths from the shore-water interface to a depth of at least 15 to 20 feet, or the maximum lake depth, whichever is less. On many Minnesota lakes, water clarity is sufficient for plant growth to 20 or more feet and sampling should include these depths on clearer lakes. In general, survey points should be established in deeper water and can be omitted in the field if surveyors determine that plant growth does not occur in deeper zones. It is much more difficult to add survey sites in-situ without biasing the placement of survey sites. Surveyors should err on sampling too deep rather than limiting sampling to only shallow waters.

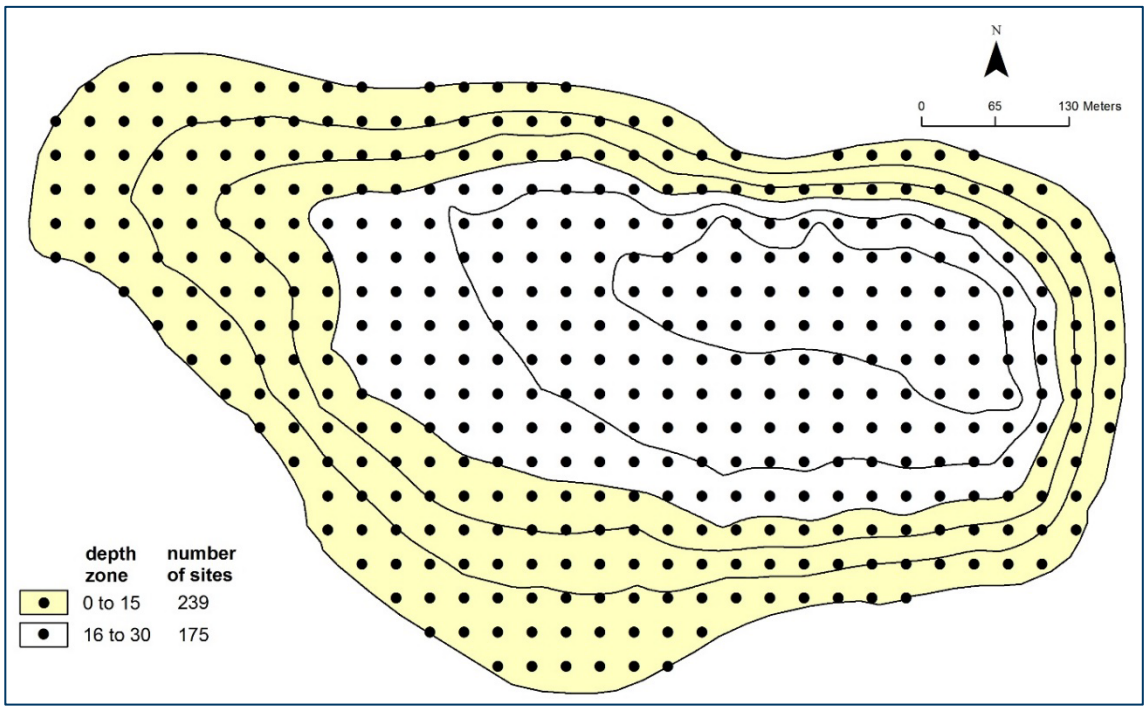
Mid-summer water clarity data may be useful for estimating the approximate maximum depth of vegetation; rooted plants often grow to depths of 1.5 times the mid-summer Secchi depth. Previous knowledge of the lake and a review of historical surveys can also provide insight on how deep to sample. A recent hydrologic map is helpful when designing a lakewide vegetation survey. A pre-survey field visit can also be used to help assess the maximum depth zone at which plant growth occurs.

With current GIS programs and GPS technology, surveyors can navigate to pre-determined sample sites with high precision. However, accurately locating the actual sample site is difficult due to inherent error in GPS readings, difficulty maintaining a fixed location with a boat, and error locating the actual sample site on the lake bottom from the boat surface. This inaccuracy is advantageous because it reduces problems associated with destructive vegetation sampling (it is unlikely surveyors will resample the exact location in subsequent surveys). This inaccuracy is minimal enough to not affect statistical analyses based on repeated sampling.

Sample site arrangement – systematic grid or stratified grid

Madsen (1999) recommends using GIS and GPS to establish sample sites systematically along a grid across the survey area. This is particularly useful when surveyors are interested in estimating the distribution of vegetation; a purely random distribution of sample sites may result in large un-sampled areas of the lake. While a grid ensures even placement of sites across the basin, it often results in an uneven distribution of points across the depth gradients. Near-shore, shallow sites (that may contain the highest plant diversity), are often under-sampled while deeper water sites tend to be over-sampled (Figure 6-3). In these situations, stratifying sample site placement within an area of interest (Yin et al. 2000) helps to ensure adequate sampling (Figure 6-4).

Figure 6-4 Simple grid placement of sample points



If sample sites are stratified, more sites should be placed in shallow water where vegetation is likely to be more diverse and abundant; fewer points should be sampled in deep water where vegetation is typically sparse, and a lower number of sample sites may adequately assess vegetation.

Even with stratification, near-shore vegetation, particularly emergent and floating-leaf stands, may be under-sampled with this method, often because surveyors cannot physically navigate through these stands without damaging the plants. To compensate for this shortcoming, sampling protocols are outlined in Chapter 4 to delineate, map and describe emergent and floating-leaf habitat and other unique aquatic plant communities and in Chapter 7 to describe near-shore plant communities. Surveyors are strongly encouraged to consider the use of those survey types when a point-intercept survey is conducted.

Required sample number for frequency data

The number of sample sites required to reliably estimate species frequencies (Newman et al. 1998) can be calculated using the formula: $N= (t/D)^2*(1-p)/p$, where:

N= required sample size
t = appropriate value from t distribution table (1.96 for 95% confidence interval)
p = estimate of frequency of occurrence
D = error as a fraction of p (i.e., 0.1 to estimate p within 10%)

The error associated with frequency data is proportional with the highest error at intermediate frequencies (Newman et al. 1998). A high number of samples are needed to detect plants that occur at low frequencies and to detect small changes in frequencies (Mikulyuk et al. 2010). Sample size should be determined based upon the range of frequency difference desired to detect and the acceptable probability of not detecting that difference (Whysong and Brady 1987). Unless plant frequency is high (50% or higher), detecting changes in vegetation frequency of plus or minus 10% with a high degree of success can only be obtained with sample sizes approaching 500 (Table 6-1). For aquatic plant surveys, Nichols (1984) recommended that the most frequently occurring species should be used for calculating the adequacy of the sample and added that it may be appropriate to accept a greater error (for example 15% error instead of 10%) to reduce sampling effort.

Table 6-1 Required sample number for frequency data using 95% confidence limits, 10% or 20% error

Frequency of vegetation	Required sample number for 10% error	Required sample number for 20% error
10%	3457	864
20%	1537	384
30%	896	224
40%	576	144
50%	384	96
60%	256	64
70%	165	41
80%	96	24
90%	85	21

The size of the littoral zone influences the actual number of points and the grid resolution (spacing between points). Newman (1998) concluded that sample sizes do not need to be adjusted for lake size and smaller lakes should receive as much effort as larger lakes. But on larger lakes, increasing sampling may provide additional information on species spatial distribution. Existing information about the plant community should also be considered when determining sample site number and spacing. For example, while the physical littoral zone may extend to 15 feet and deeper, on many lakes vegetation may be restricted to shallower depths. In these situations, sample points should be concentrated within the actual vegetated zone.

Sample number and grid spacing

A minimum of 225 sample sites should be surveyed in each lake to estimate the percent littoral zone that contains vegetation and be 95% confident that frequency estimates are within +/-20% of the estimated true value. If a higher level of confidence and/or lower error is desired, more sites should be sampled. Fewer points may be sufficient if the main objective is to simply assess the plant community and statistical comparisons between survey years are not needed.

Surveyors should consider stratifying sample sites by water depth to ensure adequate sampling within important depth zones. Contour lines at five feet increments are available for most Minnesota lakes and can be used to stratify sample sites. A minimum of 75 points should be sampled in both the 0 to 5 feet depth zone and in the 6 to 10 feet zone; these shallow zones are most likely to contain vegetation as well as high species richness. In each deeper strata surveyed, a minimum of 50 points is recommended (Table 6-2).

Table 6-2 Recommended minimum sample number by depth strata for point-intercept surveys

Depth strata (feet)	Minimum number of points	Acres in depth strata	Spacing of points (meters)
0 to 5	75	<75	<65
		75-150	65
		75-150	≥65
6 to 10	75	<50	<65
		75-150	65
		75-150	≥65
11 to 15	50	<50	<65
		75-150	65
		75-150	≥65
16 to 20	50	<50	<65
		75-150	65
		75-150	≥65
21 to 30	tbd	<50	<65
		75-150	65
		75-150	≥65

The default spacing for points in each stratum will be 65 meters (one point per acre) unless:

1. Minimum sample number for that stratum is not met (then decrease spacing)
2. Sample number for that stratum requires excessive survey effort (then increase spacing)

On most lakes, sample points will be placed 65 meters apart, which will result in approximately one sample point per littoral acre. LEU has used 65 meter spacing as a standard spacing but sample spacing has ranged from 200 meters on very large lakes (Leech), to 150 meters on moderately large lakes (Ten Mile, Woman) to 40 meters on small lakes or lakes with narrow littoral zones. The minimum distance between sample points is determined by the accuracy of the GPS and, with current technology, a minimum distance of 30 meters is recommended to avoid overlap of sampling location. A two-person crew can generally survey between 100 and 200 sample sites per day, but the actual number depends on surveyor experience, plant density and ability to navigate through sites, plant diversity and drive time to lake.

Individual survey area size

For boat-based sampling using rakes, the individual survey area is restricted to the area covered by a single rake toss, or about a $1m^2$ area. A single rake toss is used at each site to help ensure consistency between sample sites. Surveyors should not enlarge the survey area on an ad hoc basis – for example by including species that are visible "just outside" of the survey area and/or by tossing multiple rake tosses at each site. This should not be done because it creates unequal survey areas if not done consistently and the multiple rake tosses are in effect "subsamples" that are statistically related to each other. An additional problem is created at sites with steep depth contours, where multiple rake tosses at the same site are likely to sample unequal depths. For statewide and lakewide consistency, only one rake toss should be used at each site.

Pre-survey preparation

Training

LEU provides training and technical assistance on Point Intercept Survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data are recorded electronically or on paper forms (Appendix C).

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual). Survey point waypoints are created (GIS Manual) and uploaded to handheld GPS units. When generating survey points, first establish draft sample sites in GIS and use trial and error to determine final sample site number and placement. It is sometimes easier to create a grid of points at equal spacing throughout the survey area and then modify that grid if deemed

necessary. For example, within certain depth strata, surveyors could eliminate every other point to reduce sample site number.

Conducting the survey

Sampling is conducted primarily from a boat and GPS units are used to navigate to each sample point. The sample points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units, and the shifting movement of the boat due to wave action, surveyors are not always able to stop precisely on the sample point location. Surveyors are directed to navigate to within five meters of sample point coordinates shown on the GPS unit. The boat operator maintains the position of the boat without anchoring.

To avoid bias in sampling, surveyors preselect one side of the boat where sampling will occur. The survey area is approximately one square meter (1 m by 1 m). In shallow water, it may be feasible to use a premeasured plastic hoop to delineate the survey area, but for most sites, the survey area is only approximate. Actual survey area dimensions will vary slightly between surveyors and with wave conditions. Surveyors should be conservative in estimating the survey area and not include vegetation that is well outside the $1m^2$ sample site.

Determining maximum sampling depth

Surveyors record the maximum depth that was consistently sampled (all sites at this depth and shallower are surveyed or the reason for omission is recorded). Progressive sampling may be used to determine the maximum sampling depth: for example, surveyors may begin by sampling to a maximum depth of 30 feet but if they fail to find vegetation in depths greater than 15 feet, they may reduce their maximum sampling depth to 20 feet if all sites within the 0-20 feet depth zone are sampled. If surveyors need to reduce sampling in the field to complete a survey in a timely manner, sample sites should be omitted in a systematic manner (for example, every other sample site should be omitted).

Some protocols use the presence or absence of vegetation at a sampling point as an indicator of whether they should sample the next nearest point on the grid. This is not recommended because it can produce a dataset where some depth zones are not fully sampled, and it is difficult to determine the percent of the depth zone that was sampled (Figure 6-5). Instead, sampling should be based on minimum sample number by depth zone, regardless of whether vegetation is detected (Figure 6-6).

Figure 6-3 Sampling pitfall - sampling based on detection of vegetation at adjacent sites

This strategy may result in inadequate sampling of important zones

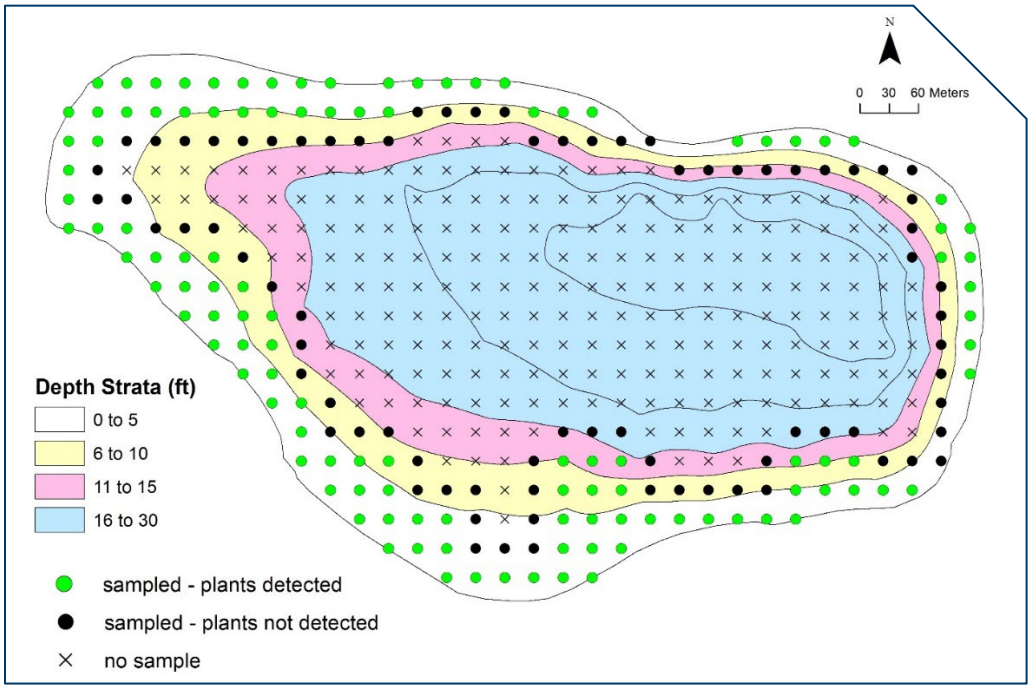
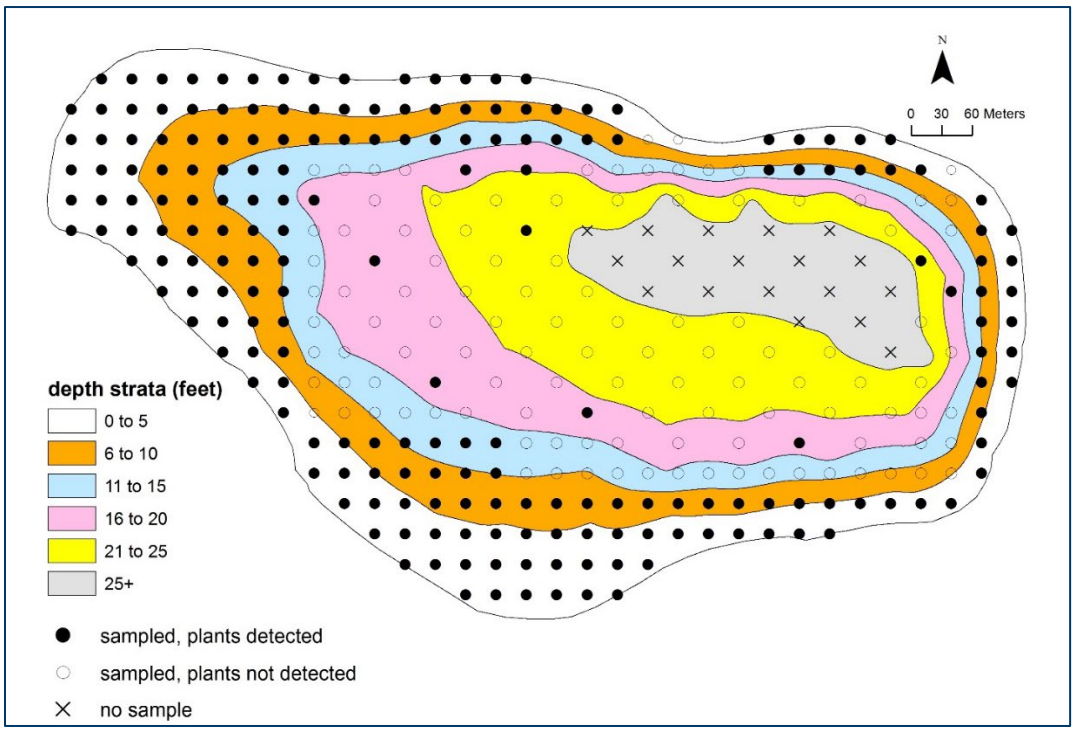


Figure 6-4 Stratified sampling with minimum sample number by depth zone



Survey site accessibility

Surveyors should attempt to sample all sample sites within the targeted depth zone. On shallow lakes, survey sites will be sampled across the entire lake (Figure 6-7). On deep lakes with even contour lines, there will be a defined deep-water zone beyond which no sampling occurs (Figure 6-8). On deep lakes with offshore shallow bars and/or irregular contours, it will be difficult to predict which sites are to be sampled until the water depth is measured at each site (Figure 6-9). If any sites within the pre-designated survey area are not surveyed, surveyors record the reason for omitting sites so that omitted sites can be distinguished from surveyed sites where vegetation was not detected. The reason for not sampling a site is recorded:

1. Too deep - occurs in water depths greater than the predetermined sampling depth. As surveyors progress along a row of points (from shallow to deep water) they may encounter sites that exceed the maximum sampling depth. Surveyors should record the depth for these sites, particularly if the depth is near the maximum sampling depth (see example). These sites are retained in the database.
2. Emergents - site location is within a dense and/or shallow stand of emergent or floating-leaf vegetation and motoring into the site would likely destroy vegetation (surveyors may record general observations about the site, including dominant species within visible area, but do not include data in calculations)
3. Shore - site location is on shore (sample station is permanently removed from database)
4. Other - access to site is prevented by structure or activity including dock, swim area, other boats, and herbicide application.

Figure 6-5 Point-Intercept Survey on Shallow Lake

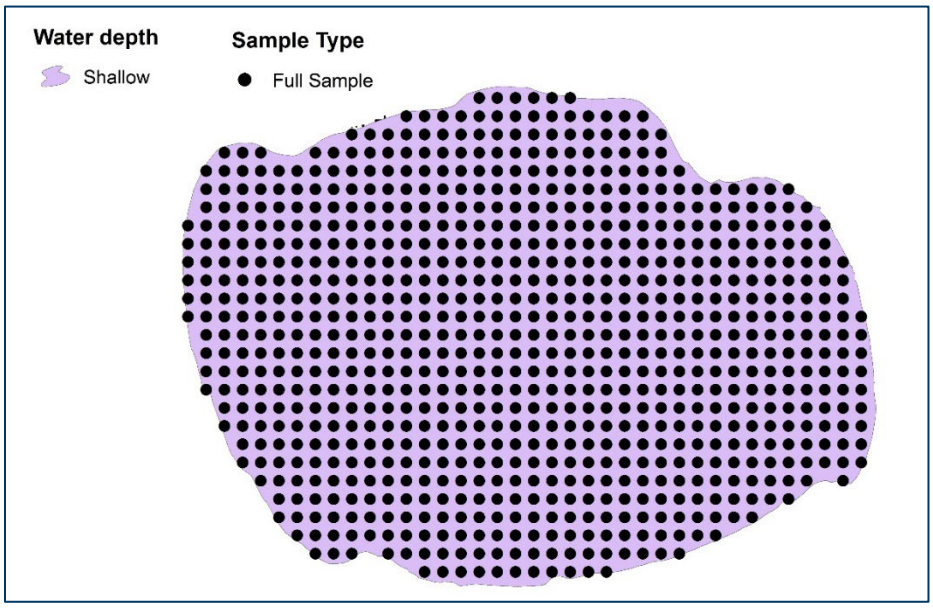


Figure 6-6 Point-Intercept on Deep Lake with Regular Contours

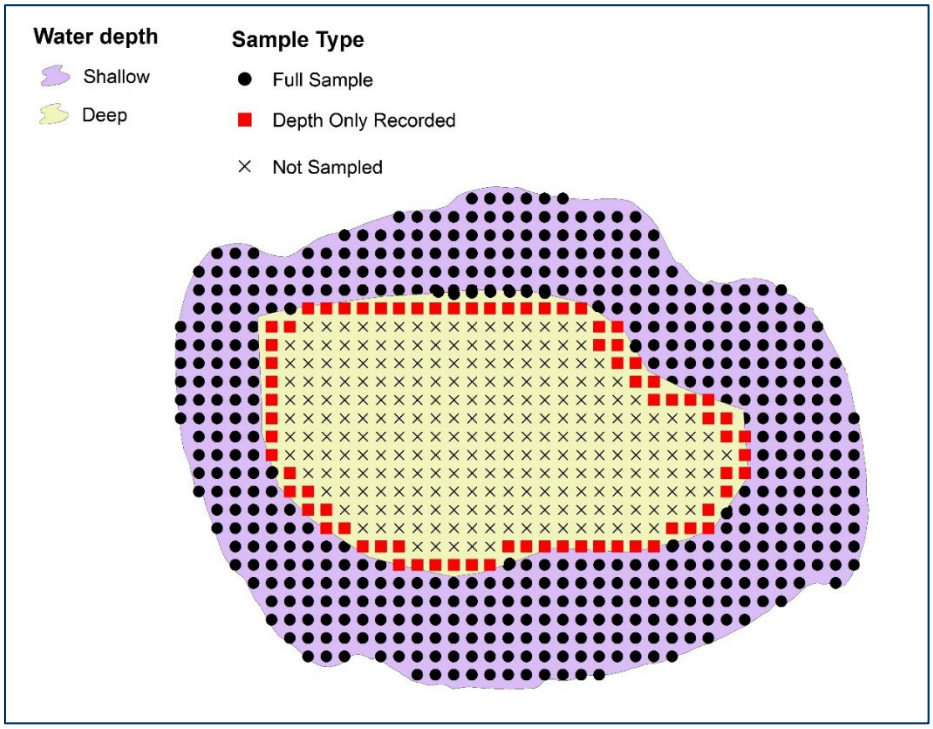
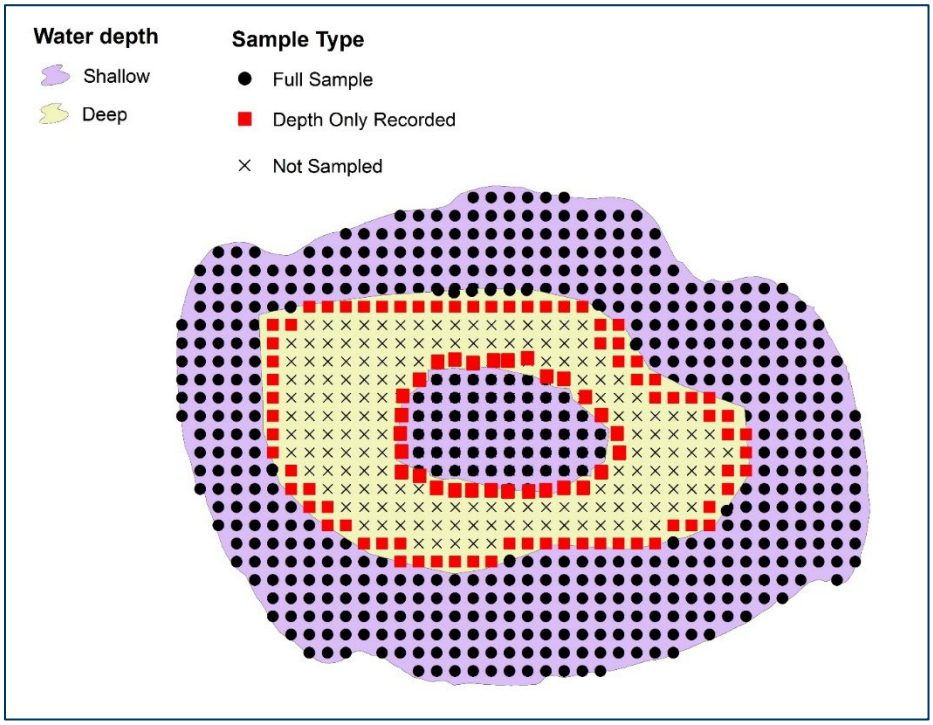


Figure 6-7 Point-Intercept Survey on Lake with Irregular Contours



Water depth

At each sampled site, water depth is measured as close to the actual vegetation and substrate sample site as feasible. In water depths less than eight feet (2.5 meters), surveyors use a measuring stick, or the rake handle marked in one-foot increments; an electronic depth finder is used in deeper water. Water depth is recorded to the nearest foot, or to the quarter foot in depths less than one foot. On lakes with steep contours, the water depth at the boat stern may be several feet different than the depth at the boat bow. In this situation, orienting the boat parallel to shore may help mitigate errors in depth estimates.

Substrate sampling

Substrate is sampled only in shallow sites of seven feet (two meters) and less and should be sampled at the same site where vegetation is sampled. Surveyors tap a pole into the lake bottom to evaluate lake substrate. Soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes (Table 5-2) are recorded. If several substrate types occur at a site, surveyors record the most common type.

Vegetation sampling

Sample Site

At each site, plants within an approximate $1m^2$ area are sampled visually and with a rake sampler (see Appendix B). This is not a plot sample where the boundaries of the sample area are delineated. The main goal in tossing the rake is to collect a representative sample of vegetation at the sample site. A $1m^2$ area is suggested to help maintain consistency between surveyors and between sites. It should not be inferred as the appropriate sample area to estimate site level taxa richness or plant cover. A surveyor's ability to approximate a $1m^2$ area is complicated by boat movement and was water depth increases. Surveyors must balance their attempt to sample a $1m^2$ area with their need to ensure the rake hits the lake bottom and contacts a sufficient area of vegetation to collect a sample. The rake should be tossed only once and dragged not more than 3 to 5 meters (about a 16 feet boat length). If the rake is tossed multiple times and/or dragged for longer distances, it will likely cross multiple depths and include vegetation that is outside the intended $1m^2$ area. The rake should not be thrown a second time simply because no vegetation was detected on the first rake toss. If surveyors question whether the rake is contacting the lake bottom, they should temporarily halt the survey and conduct sampling tests to determine if the rake is sufficiently weighted and if wind conditions are appropriate to permit sampling.

Subjective estimate of abundance

Frequency of occurrence, or detection at each sample site, is the metric assessed in this method. If surveyors are interested in assessing plant cover, density, biomass or other features, they should use

additional and/or alternative methods. With that clarification, surveyors may find it useful to record a subjective estimate of "abundance" at each site. Abundance estimates described for point intercept surveys are subjective but may be helpful for managers to describe lake areas of potential recreational use issues.

If true cover estimates are required, a plot-based survey is required. Abundance estimates are influenced by water depth, visibility, plant taxa, time of year, and individual surveyor bias. Some surveyors elect to use "rake coverage" or the approximate area of the rake covered by vegetation as an estimate of abundance. These estimates are highly variable and if used should be defined and calibrated by taxa (Yin and Kreiling 2011). Estimates are also relative to the individual lake. What may be "abundant" on one lake may be relatively "common" on another. To minimize confusion and to increase agreement within a specific survey, surveyors should meet on the lake before the survey and agree on the specific categories for that survey.

We provide some general descriptions of abundance categories (Figure 6-10). For each site, total plant abundance is described as one of the four categories:

1. Not detected within survey area
2. Sparse: only one or few fragments collected on rake or visible in water within a $1m^2$ survey area
3. Common/frequent/occasional: neither sparse nor matted
4. Abundant/matted: plants at or near surface, generally making boat navigation difficult

Because these abundance estimates will be lake specific, we recommend surveyors pre-determine more specific descriptions for their survey and review the categories as a team before surveying. We recommend taking example photographs of each category for reference during and after the survey.

Plant identification

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible. Vascular plant taxonomy follows Crow and Hellquist (2000) and nomenclature follows MNTaxa (2015). Collection of voucher specimens are recommended for all taxa observed during survey. Procedures for collecting, labeling and preserving voucher specimens are provided in Chapter 9.

Surveyors may record specimens as "unknown" if insufficient plant material exists for identification. If sufficient plant material is collected but the surveyor is not familiar with the plant, they may temporarily record the specimen as "unknown" and preserve the specimen for later identification.

Figure 6-10. Example photos of subjective estimates of abundance

Example of plant conditions surveyors may elect to describe as “Sparse” (on some lakes, surveyors may place these into the “Common” category if they frequently encounter sites with even less vegetation).





Sparse





Common



Abundant



Abundant

Off-grid sample sites

Off-grid sample sites are an option when surveyors want to collect georeferenced data that would not otherwise be collected at specific grid survey points. Off-grid sample sites are subjectively established, and a GPS location is recorded. A common use of off-grid sites is to report any additional plant taxa observed outside of the pre-established sample sites. These data are used to compile a lakewide species list but are not used in frequency calculations. Surveyors may also record information about general plant condition, particularly if the survey objective is to monitor plant management activities. Off-grid sample sites are not a substitute for inadequate sample number; if surveyors determine that the original grid of sample sites is inadequate then additional sample sites should be objectively added using GIS software.

Data management and analysis

Data collected with this method can also be used to:

- Develop GIS-based, lakewide distribution maps for the common species
- Estimate the maximum depth of rooted vegetation
- Describe the shoal water (0 to 7 feet) substrate types
- Assess changes in overall vegetation and frequently occurring taxa

Plant taxa richness

Data obtained from lakewide point intercept surveys can be used to estimate lakewide plant taxa richness, or the number of plant taxa present in the lake (Radomski and Perleberg 2012). Taxa richness at each individual sample site can also be tallied, but caution should be used when comparing these individual site estimates between sites and between years. The rake toss sample site size (approximately $1m^2$) is typically too small to adequately assess site-specific species richness (see Chapter 7). It may be more appropriate to assess and compare collective richness values within broader depth zones and lakewide.

Frequency of occurrence

Frequency of occurrence is calculated for all vegetation and for specific taxa as the number of sites in which a target plant occurred divided by the total number of sampled sites. Frequency is calculated for the entire sampled area and by water depth intervals. Results should indicate if significant portions of the basin were not surveyed, and the resulting frequency data are applicable only to the surveyed zones.

It is important to record the maximum depth strata where all sample sites were surveyed and the total number of sample sites from shore to this depth. Frequency of occurrence values should be reported

along with the sampled depth zone, the total number of sample sites and the sample site size. The error associated with this estimate can be provided with a specific confidence interval:

$D = t\sqrt{(1-p)\,(p)/N}$

Where:

D = error as a fraction of p (e.g., 0.1 to estimate p within 10%)
t = appropriate value from t distribution table (1.96 for 95% confidence interval)
p = estimate of frequency of occurrence
N= sample size

Example: Within the shore to 20 feet depth zone, plants occurred in 30% of the $1m^2$ sample sites (N=250). There is 95% confidence that this value is within 6% of the estimated value (24% to 36%).

Error = $1.96\sqrt{\ (0.70*0.30)/250} = 0.06 = 6\%$

Before-and-after analyses or comparisons between surveys for all vegetation, or for given species, can be made using a two-by-two or Chi-square analysis using the actual numbers of intervals with and without the species (Madsen 1999). Use the actual number of observations rather than frequencies (or percentages) for the statistical test.

Chapter 7 Quantitative Nearshore Plots

Objectives

The protocol of this chapter standardizes the collection of a lake plant taxa list within the near-shore, shallow water zone where the highest diversity of species is expected. Because the near-shore zone typically contains the highest diversity of taxa, and most taxa occur in this zone, data from this method can be used to estimate lakewide taxa richness.

Introduction

Estimates of plant community richness, or number of taxa, are influenced by the areas selected for searching. Searches are most successful if surveyors target lake areas where a high number of plant taxa are likely to occur but determining where those areas occur is not straightforward and leads to non-standardized efforts (different surveyors may select different search areas and produce different search results). Investigators can standardize their searches by systematically placing sample sites within the near shore.

Search effort (time spent searching and/or total area searched) also influences estimates of plant community richness. LEU staff conducted pilot near-shore sampling on high diversity lakes and used those data to select 25 m^2 as the appropriate survey area size for richness sampling. Increasing survey area size did not result in a significant increase in species richness estimates.

While this method has some similarities to the Transect Method, it provides a more efficient way to collect a species list because the survey area size is standardized on the near shore. Additionally, surveyors are more likely to view inconspicuous taxa by wading than from a boat. Because this survey is restricted to the near-shore zone, several deep-water taxa may be missed. Examples of taxa that are more likely to occur in deep water include coontail (*Ceratophyllum demersum*), floating-leaf pondweed (*Potamogeton natans*), Robbin's pondweed (*Potamogeton robbinsii*), white-stem pondweed (*Potamogeton praelongus*), stonewort (*Nitella* sp.), and aquatic bryophytes. As with other surveys described in this Manual, as surveyors navigate between survey sites, they should record any additional species they detect outside of the survey areas as "present in the lake but not detected within survey sites". These are categorized as "off grid" sample sites.

Data from this survey can also be used to supplement the taxa list obtained in the point-intercept survey, particularly if that survey design had a limited number of sample points in shallow water. However, since frequency data are expressed in relation to sample size area, the frequency data from

the 25m^2 survey sites cannot be combined with or directly compared to frequency data obtained from the 1m^2 point intercept survey sites because survey area differs between those surveys.

Survey Design

Defining the survey site area and establishing survey sites

The surveyable zone is the narrow band extending from the shore-water interface lakeward 5 meters. Within this zone, survey sites, measuring 5 meters along the shore by 5 meters lakeward (Figure 7-1) are established in a systematic, regular interval along the lake perimeter. Survey site locations are established using the same protocol used to establish Score The Shore survey sites (Figure 3-1). If a Score The Shore survey has or will be conducted on the lake, those survey site locations (the center point of the established 100 feet shoreline segment) may be used for the near-shore sites.

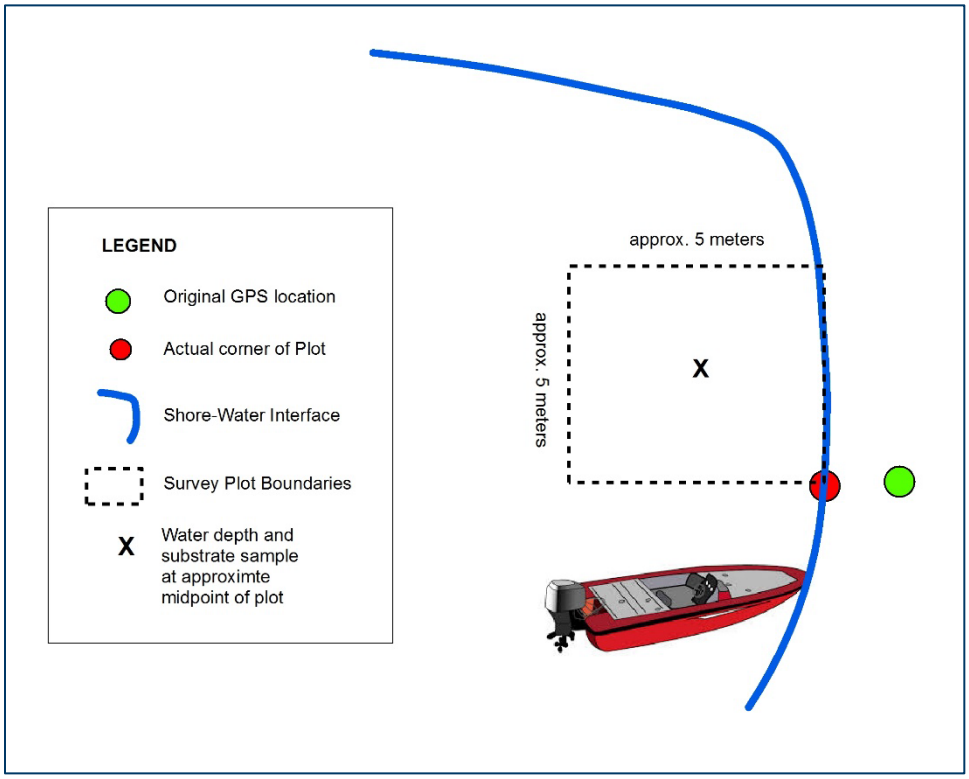


Figure 7-1 Near-shore sample site

The recommended minimum number of survey sites per lake is 20. The spacing of survey sites and the total number of survey sites are determined by the length of the shoreline (Table 7-1). On lakes with 3.3 to 15 miles of shoreline, survey sites are spaced 200 meters apart. Survey sites are spaced closer together on lakes with less than 3.3 shoreline miles and further apart on lakes with more than 15 shoreline miles. On very small lakes with less than 1.22 shoreline miles, surveyors place 20 sample sites at equal distances around the shoreline and that distance may range from 60 to 95 meters. This survey is designed for lakes with shoreline lengths of 50 miles or less. It can be conducted on large lakes, such as Mille Lacs, Leech, and Rainy, but surveyors should consider the feasibility of assessing such large shoreline areas; it may be useful to target specific bays or shorelines on these large lakes rather than attempting to survey the entire shoreline.

Table 7-1 Determining spacing for near-shore sites

Shoreline length (miles)	Spacing of sample sites (meters)	Number of sample sites per lake
0.75-1.21	Varies 60 to 95	20
1.22-2.24	100	20-36
2.25-3.29	150	24-35
3.30-14.99	200	27-121
15.00-50.00	400	60-201

Pre-survey preparation

Training

LEU provides annual training and technical assistance on Nearshore Plot Survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix B. Data can be recorded on paper forms (Appendix C) or electronically.

For lakes that have not been recently surveyed, surveyors should review the lake boundary outline in GIS and update if needed (GIS Manual). Survey point waypoints are created (GIS Manual) and uploaded to handheld GPS units.

Conducting the survey

This survey is conducted by wading in shallow water, or by boat if water depth and/or substrate prevent wading. The survey points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units and the uncertainty associated with the GIS coverage of the shore-water interface boundary surveyors are not always able to navigate precisely to the survey point location.

Surveyors navigate to the survey site with GPS but land the boat at a distance from the survey site to avoid disturbing the site. The waypoint marks the right, shoreward corner of the site as the surveyor faces the shore (Figure 7-1). At each site, surveyors approximate a 5 meter by 5-meter area, with one side of the survey site along the shore-water interface. As a general guide, most MNDNR survey boats are about 16 feet (5 meters) in length. This is a rapid assessment method, and it is not necessary to measure the survey area dimensions in detail. Actual survey area dimensions will vary slightly between surveyors and site conditions. Surveyors should be conservative in estimating the survey area and not include vegetation that is well outside the $25m^2$ survey area.

Water depth

At each survey site, water depth is measured at the mid-point of the survey site (Figure 7-1). Surveyors use a measured stick, or the rake handle marked in one-foot increments. Water depth is recorded to the nearest foot, or to the quarter foot in depths less than one foot.

Substrate sampling

Surveyors describe the substrate, in approximately the middle of the plot, by tapping a pole into the lake bottom to evaluate lake substrate. Soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes (Table 5-2) are recorded. If several substrate types occur at a site, surveyors record the most common type.

Vegetation sampling

At each site, plants within the $25m^2$ area are sampled visually. A view tube or snorkel may be used to survey the area. A rake may be used to supplement sampling, particularly if water clarity and/or depth limit visibility. The rake may be tossed multiple times to ensure the area is sufficiently sampled but surveyors should not toss the rake outside of the survey area. Surveyors should note any additional taxa that are observed outside of survey sites, but those taxa will not be included in frequency of occurrence estimates.

For each site, total plant abundance is described as one of the following categories (for more information see Chapter 6):

1. Not detected within survey area
2. Sparse: only one or few fragments visible and/or collected on each rake toss
3. Common/frequent/occasional: neither sparse nor matted
4. Abundant/matted: plants at or near surface, generally making boat navigation difficult

At each site, all plants observed are recorded. Taxa are identified to the species level when feasible. We recommend voucher specimens be collected for all taxa observed (Chapter 11).

Data management and analysis

Data are managed by individual programs.

Data collected with this method can also be used to:

- Estimate near-shore plant taxa richness, or the number of plant taxa present in the near-shore (in many lakes this may be a good proxy for lakewide taxa richness)
- Develop GIS-based, near-shore distribution maps for the common species
- Describe the shallow water (0 to 4 feet) substrate types
- Assess changes in near-shore vegetation and frequently occurring taxa
- Evaluate potential relationships between near-shore plant communities and shoreland management practices assessed with Score The Shore survey

Chapter 8 Hydroacoustics

Objectives

The hydroacoustic survey is designed to assess the distribution of submerged vegetation on a lakewide or bay-wide scale. This survey is designed to, with moderate effort, assess changes in frequency of occurrence and plant height statistics by depth strata. The main metric assessed is “biovolume” which can be generally defined as the percent of the water column occupied by vegetation (Valley and Drake 2007).

Primary goals include:

1. Describe the geographical distribution of submerged vegetation throughout the littoral zone and within specific depth zone intervals.
2. Estimate the biovolume of vegetated covered areas of the lake bottom.
3. Compare the submerged vegetation biovolume across years.

This survey does not collect taxonomic information on plant communities and managers may elect to use it in combination with a Transect, Point Intercept, Nearshore Plots and/or Botanical Inventory Surveys.

Introduction

Submerged vegetation communities are dynamic, reflecting the varied life histories and environmental preferences of their species, e.g., nutrient availability, wind exposure, bottom substrate, water level fluctuations, and water depth (Wetzel 2001). While, quantification of submerged plant abundance is important, abundance estimates are expensive to obtain and are highly variable across littoral areas (Downing and Anderson 1985).

Investigators have used hydroacoustics, or transmitted sound pulses in water to sample aquatic plants for over 30 years (Maceina and Shireman 1980). One of the main advantages of this remote sensing technique is that sound travels quickly in fresh water (~1480 m/s), so the entire water column can be sampled almost instantaneously using mobile survey techniques. The distance between the transducer and an acoustically reflective target (e.g., aquatic plant) can be calculated based on the time delay between an emitted signal and a return signal using the velocity of sound in water (Simmonds and MacLennan 2005). The resulting information can be used to estimate aquatic plant abundance and height. Sabol et al. (2002) noted that the acoustic reflectivity of submerged macrophytes was likely based on the presence of gases within the leaves and stems of plants so that more buoyant plant species were more acoustically reflective. Thomas et al. (1990) published one of the first studies that

determined hydroacoustic techniques yielded substantially greater precision of biovolume estimates and lower data collection costs than SCUBA-based estimates.

There are multiple hydroacoustic systems available to assess aquatic plant communities. One of these, the BioBase system, provides a cost-effective method to identify areas of dense or matted submerged macrophytes for the purposes of aquatic plant management. This system can quickly create maps of dense vegetation when surveyors adequately cover an area of interest, although BioBase may produce different estimates plant heights compared with other systems (Radomski and Holbrook 2015). Hydroacoustics survey techniques are unique with regards to submerged plant assessment in that this approach allows large-scale assessment of submerged plants. However, standardizing data collection equipment and the signal processing approach is necessary prior to using this technology as an assessment tool (Radomski and Holbrook 2015).

Survey design

Defining the survey area

The survey area should include the area of the lake where information on aquatic vegetation is needed. This may include areas that may not be vegetated during the current survey year but were vegetated in past years or where it is anticipated that they will be vegetated in future years. This is particularly important if the survey objective is to compare data between survey years. In most lakes the survey area will include all water depths from the shore-water interface to a depth of at least 15 to 20 feet, or the maximum lake depth, whichever is less. On many Minnesota lakes, water clarity is sufficient for plant growth to 20 or more feet and sampling should include these depths on clearer lakes. As with point-intercept surveys, hydroacoustic surveys should error on sampling too deep rather than limiting sampling to only shallow or mid-depth waters.

Mid-summer water clarity data may be useful for estimating the approximate maximum depth of vegetation; rooted plants often grow to depths of 1.5 times the mid-summer Secchi depth. Previous knowledge of the lake and a review of historical surveys can also provide insight on how deep to sample. A recent hydrologic map is helpful when designing a lakewide vegetation survey. A pre-survey field visit can also be used to help assess the maximum depth zone at which plant growth occurs.

Transect arrangement or Track Design

Two options can be considered in designing hydroacoustic sampling. First, hydroacoustic sampling can be conducted using numerous transects that are selected to provide a range of depth, substrate, and aquatic plant abundance. If a point intercept survey is also being conducted, one could set transects on the same grid as the point intercept with the orientation of the transects selected that best covers the littoral area of the lake. The number of transects depends on lake size, resources, and precision of the

abundance estimates needed. For the creation of biovolume maps, consult the hydroacoustic systems' documentation. Transects should be standardized for a lake, and the same transects should be used if a lake is resampled. Alternatively, if biovolume maps are not the objective, hydroacoustic sampling can be completed using a zigzag pattern to systematically sample the entire littoral area. A zigzag pattern can be designed to ensure representative sampling of the entire littoral area by applying a systematical random pattern using GIS. First, evenly spaced shoreline points are created around the lake. Second, points are created at approximately equidistant locations between shoreline points and at water depths exceeding the depth of plant colonization. The points are then connected to form the zigzag pattern.

Pre-survey preparation

Training

LEU provides training and technical assistance on hydroacoustic survey method on request.

Equipment and GIS preparation

A checklist of required and recommended field equipment is provided in Appendix C. Transects are created and uploaded to handheld GPS units. Hydroacoustic data are collected with the Lowrance High Definition System consumer echosounder integrated with wide area augmentation system-corrected GPS and Installed as recommended by the manufacturer. Typically, a single-beam 200-kHz transducer (20° x 20° half-power beam angle) is oriented vertically and mounted on the boat stern.

Conducting the survey

Consult and review your hydroacoustic system's documentation prior to conducting the survey, data uploading, and data processing. Use recommended settings for the echosounder unit. For example, BioBase logs data at a rate of 15 to 20 data signals per second, and GPS locations are typically recorded every second from the Lowrance HDS. Since BioBase analyzes data by aggregating by time, it is critical to maintain constant boat speed; otherwise, biases in abundance will be introduced.

Standardize boat speed and then traverse transects or tracks using a consistent speed (e.g., 2 m/second). If the lake is resampled, then use the same speed as the earlier survey. Thus, it is crucial for the boat speed to be standardized when conducting a BioBase hydroacoustic survey.

Data management and analysis

Consult our organization's protocols for data management. Ideally, raw data are stored for possible reprocessing and processed data are incorporated into MNDNR GIS QuickLayers.

For BioBase, data are analyzed with their proprietary software. BioBase is a cloud-based software platform that automates acoustic and GPS signal processing and GIS data layers of estimated depth, percent of area covered by vegetation, plant height, and biovolume (percentage of the water column occupied by vegetation). Exported data include record number, latitude, longitude, bottom depth, depth to plant, and plant height. Bottom depths can be corrected for transducer depth at the time of data upload. BioBase evaluates each ping to determine if features could be extracted, and those failing this test are removed. For each valid ping, the algorithm calculates plant height as the difference between bottom depth and the top of the plant signal. Since GPS positions are typically recorded every second, bottom and vegetation features from pings that elapsed between positions are averaged. The algorithm aggregates the signals by 1-second intervals rather than a set distance, so a record typically summarized 5-30 pings along a traveled track. BioBase then processes the depth and vegetation estimates with the use of a kriging algorithm that predicts depth and vegetation values in unsampled locations based on the geostatistical relationship of the inputs. Kriging smooths feature values when variability is high but there is a positive relationship between error of kriged estimates and the distance from sampled locations.

Chapter 9 Wood Habitat Survey

Objectives

This protocol is designed to rapidly assess wood habitat within a lake by conducting a whole lake inventory or a systematic random sampling survey. The Wisconsin DNR developed this protocol (WI DNR 2020), which was adapted from a wood habitat sampling method used by the North Temperate Lake Long-Term Ecological Research program (WI DNR 2008). The largest difference between the protocol listed here compared to the WI DNR protocol is an inclusion of the systematic random sampling option for larger lakes.

This survey protocol can be used to:

1. Determine wood habitat occurrence for a lake with modest precision.
2. Detect large in-lake changes in wood habitat density over decades.
3. Assess differences in wood habitat between lakes.
4. Determine, by pooling survey data, the factors influencing the quantity of wood habitat along Minnesota lake shorelines.

Introduction

Wood habitat in lakes has many ecological benefits. Logs and fallen trees provide fish refuge, fish spawning substrate, and wildlife resting and basking sites (Sass et al. 2006, Roth et al. 2007). Lakeshore residential development reduces wood habitat in lakes (Christensen et al. 1996, Marburg et al. 2006). Management of wood habitat in lakes includes conducting inventories of this habitat, reducing wood habitat loss, encouraging natural shorelines, and adding wood back to lake nearshore areas when the estimate of loss has likely reduced fish and wildlife productivity (Sass et al. 2012, Sass et al. 2023).

Survey design

The protocol involves boating slowly along shore and recording GPS locations of wood habitat, and the wood and site attributes. The water should be clear during the survey (Secchi disk depth of 2 feet or more). For eutrophic lakes, surveys should be conducted in spring or fall. If the Secchi depth is less than 2 feet, this protocol should not be used as visual estimates of woody habitat are likely unreliable.

The survey distinguishes between two types of wood habitat:

1. beaver houses/food caches
2. large wood

Large wood is defined as any tree log or branch at least 4 inches in diameter at any point along its length and at least 5 feet in length (10 cm x 1.5 m). Record wood of sufficient size when it occurs between the ordinary high water level (OHWL) and the 4-foot depth contour.

“Large wood” includes wood of sufficient size found:

- submerged or on the water surface in shallow (0 to 4 feet) water.
- lying on the ground during low water periods, but still below the OHWL.
- tree roots that occur below the OHWL.
- live branches and non-anchored logs that occur below the OHWL.
- live or dead tree branches hanging over the water that occur below the OHWL.

Do not record:

- lumber (e.g., railroad ties, fish cribs, wood retaining walls).
- wood buried in the sediment.
- wood above the OHWL.

Pre-survey preparation

Lake size determines the survey type. For small lakes (shoreline miles less than ~10 miles) with a low or modest amount of wood, the entire shoreline of the lake should be surveyed. For large lakes or lakes with large amounts of wood, surveys should utilize systematic random sampling stations. Sampling stations will be spaced at standard shoreline lengths (e.g., 100, 200 or 400 m), depending on lake size and likely density of wood. GIS software is used to create these shoreline segments around the lake perimeter. A GIS tool has been developed to establish shoreline segment stations (refer to the latest GIS tipsheet or manual to complete this task). If a wood habitat survey has been previously conducted for the lake, then surveyors should strongly consider reusing the original shoreline segment stations.

Since large wood greater than 4 inches diameter and 5 feet long that is in the water and/or below the OHWL will be recorded, it is important that the surveyors are familiar with wood of this size. There are several ways to ‘calibrate’ your eye. The surveyor could have a pole marked in 1-foot increments and a 4-inch log end in the boat for reference, or the surveyor can measure a few logs in the field until confident about their quick visual assessment of size.

Conducting the survey

After confirmation of sufficient water clarity and an assessment of OHWL, begin survey.

1. Record survey details, including the type of survey:
    a. whole lake
    b. systematic random sampling survey

        i. record the station number
2. For each beaver house or food cache:
    a. Record GPS location
    b. Record condition of the submerged wood:
        i. Recently submerged (Yes/No)
    c. Record a *branchiness* ranking:
        i. Heavily branched
        ii. Consists of poles with fish hiding spaces
        iii. Few fish hiding places
3. For each piece of large wood (at least 4-inch diameter and at least 5 feet in length) that is between the OHWL and the 4-foot depth contour:
    a. Record GPS location
    b. Record if the log has at least 5 feet of its length underwater
    c. Record a *branchiness* ranking:
        i. Log with no branches
        ii. Log with few branches
        iii. Full crown
    d. Record if the wood crosses or touches the OHWL (Yes/No)
    e. Record source:
        i. Unknown
        ii. Stump or standing tree in water
        iii. Beaver log drop
        iv. Human (e.g., saw marks, log addition project)
    f. Record land use class (use Score the Score classifications)

Data management and analysis

Field data collected with an ArcGIS app will be synced to a geodatabase. The data steward will contact the surveyor on potential data quality issues.



Figure 9-1. From left to right, wood without branches, with branches, and with full crown. Source: Wisconsin DNR.

Chapter 10 Aquatic Botanical Inventory and Rare Aquatic Plant Species Surveys

Objectives

This chapter describes qualitative lake survey methods and considerations to employ when pursuing the following objectives:

1. Compile a species list through botanical inventory of aquatic vascular and non-vascular plant species

2. Document new locations of rare and uncommon aquatic plant species

Introduction

Many aquatic plant species, and rare species in particular, have unique habitat preferences or requirements and/or life history traits that limit their distribution in the state and within a waterbody. Even if appropriate habitat is available within a waterbody, some plant species may still occur infrequently. Systematic surveys with objectively selected sites, such as transect (Ch. 5), point-intercept (Ch. 6) and nearshore plots (Ch. 7) surveys sites may fail to locate rare and less common plant species because they tend to under-sample less frequently occurring species and may not include small areas of unique habitat.

Therefore, aquatic botanical inventories should be conducted in appropriate lake habitats, with sufficient effort by surveyors with high botanical knowledge and expertise to ensure compilation of comprehensive species lists. Because professional judgement and experience are required to successfully locate and identify less common and obscure species, it can be difficult to standardize this type of inventory. In addition, standardized and objective procedures may result in excessive survey time without increased inventory results.

Botanists with specific knowledge of aquatic plants can often identify suites of species that may occur in certain habitat types and can thereby subjectively select survey sites to maximize their search efforts. While these survey approaches are subjective, they often result in a more complete inventory of the lake plant taxa. If quantitative estimates of species distribution and/or abundance are needed, additional surveys, such as point intercept (Ch. 6) and/or nearshore plots (Ch. 7) can be added and can be designed to target key species or address specific plant community questions.

Pre-survey Preparation

Surveyors should review existing distribution and habitat information for plants known to occur in the survey region and lake type. Consult sources such as MNTAXA, Natural Heritage Information System (NHIS), Rare Species Guide, and the University of Minnesota's Bell Museum. For many Minnesota lakes, a species list compiled by a MNDNR botanist is available on MNDNR LakeFinder.

A checklist of required and recommended field equipment is provided in Appendix A. Obtain any access permission and/or required collecting permits prior to the survey.

Search strategy

Review land ownership, access points, lake bathymetry and aerial photography to aid in search strategies. Depending on the waterbody size and search effort available to invest, a combination of strategic searching and meandering of the littoral zone around the lake can be employed. Shoreline wading or snorkeling and watercraft such as a kayak, canoe, or boat can be utilized. Inconspicuous taxa are more likely to be detected by shoreline wading, snorkeling or non-motorized watercraft than by tossing rakes from boats. Consider how to access both shallow and deep-water zones: watercraft can be used to more quickly access multiple sites in both of these zones. Visual surveying through moderate wave action or compromised clarity can be facilitated with use of a view tube (Figure A3). A double-sided rake (Figure A1) or grapple hook can be used to search for submerged plants in depths that cannot be visually surveyed.

Because this is a non-standardized survey with subjectively chosen sites, the area searched and the number of sites visited will not be used to make statistical inferences about plant taxa distribution or abundance. That said, search effort is critical because higher search effort (search time and search area) can increase the likelihood of locating species and compiling a more comprehensive list of plant species present in a waterbody. To help maximize search effort, it can be useful to predetermine a search area and/or search time. For example, a surveyor may plan to search a given shoreline stretch for 15 minutes then move to a new site if the target species and/or no new taxa are located during that time.

Survey timing

When determining survey timing, it's important to consider the life history of the target species. For example, the rare, submerged plant species, *Najas marina,* is an annual that can be found in fruit through September (MNDNR 2008). The best time to search for this species is later in the summer and thus, a survey to capture this species in late spring or early summer would not be appropriate. Multiple visits to sites may be required to locate target species at maturity.

Conducting the Survey

An appropriate and convenient starting point for both a botanical inventory and rare plant surveys may be at the point of entry to the waterbody (i.e. public water access). In general, the shallow, nearshore zone can be particularly important habitat for rare aquatic species (Myhre 1998) and is also the zone most likely to contain the highest number of plant taxa.

Botanical inventory

Navigate through the chosen survey area and record all observed taxa to the species level when feasible. Collect specimens when identification or a record of the occurrence is needed (i.e. rare species; county record) (see Chapter 9). Take note of any washed up or drifting plants that may have been uprooted by wave action or human disturbance if they have not yet been recorded.

For general botanical inventories and searches for rare species that lack defined habitat characteristics, it's important to include search areas of various habitats in the lake. These areas can include different depths, substrate types and degree of wave and wind exposure. For example, some emergent species can grow on windswept sandy shoals while floating-leaf and free-floating plants are more often found in quiet, protected bays. The deep edge of the vegetated zone should also be explored for certain submerged species, such as macroalgae and aquatic mosses, which may occur in this zone but often go undetected. Search areas should include known unique features that have potential to yield additional species such as protected bays, channels, sandy or rocky points, and islands. Also consider visiting shallow areas of intact, undeveloped shoreline, and areas where shoreline vegetation changes. Continue searching until sites of different habitat and potential for additional species have been exhausted and additional search effort does not continue to grow the species list. Sketching a species/area curve in the field can help surveyors judge the value of spending additional search time at a site.

Rare species survey

Depending on specific objectives, surveyors may elect to simply search for the target plant and not immediately record other taxa. This focused effort can allow the surveyor to cover a larger area in a shorter time. Focus the initial search area on the known habitat preferences of the target species and adjust mode of search accordingly. Consult resources such as the MNDNR Rare Species Guide and herbaria specimens to gain insight on reported associations with water depth, water chemistry, substrate type, and other plant species and plant community types.

If the target plant is located, record additional information such as location, environmental site characteristics and associated plant species. Collect a voucher specimen if appropriate to do so (Chapter 11). If possible, spend additional time on the lake to describe the distribution.

Data Management and Analysis

Rare species observations should be submitted to the Natural Heritage Information System (NHIS) following their specific requirements. An Excel worksheet template and a GIS shapefile template are available for data entry on the NHIS website. Contact the NHIS data manager, Karen Cieminski, Karen.cieminski@state.mn.us with questions.

To aid in consistent submission of data, the following are general guidelines for MNDNR staff submitting rare aquatic plant data:

1) Observation Type

- Rare plant species observations may be documented by a verified herbarium voucher specimen (preferred), a photograph, or a visual observation. Examples of situations where collection of a voucher specimen may not be feasible or appropriate include the following:
    - Plant is observed in an inaccessible site. A specific example is a population of purple-flowered bladderwort (*Utricularia purpurea*) that was in bloom in a small pond (visible from a road) on inaccessible private property. A photograph was taken to verify the plant's identity and estimate population size.
    - Collection of plant may threaten population. In most cases, rare aquatic plants are found at sites with multiple individuals and collection of a single plant will not harm the population. However, when in doubt, do not uproot a rare plant to make a voucher. Record the location of the plant and if feasible, take photographs including any flowers or fruits that may be present.

2) Point and Polygon Observations

- Surveyors submit rare plant observations using points or polygons in GIS. Factors that may influence how you report the observation include the search area size and the size of the area where you observed the plant.
    - Point observation: A point is most appropriate for a single observation site where the surveyor did not search beyond the point. Rare aquatic plants observed at individual stations on a Point Intercept survey are usually best documented with a point shapefile.
    - Polygon observation: A polygon may be used to document a rare plant observation at a site where the surveyor searched a known area of suitable habitat, and the polygon shape and size represents the approximate area where the plant was found. It is helpful to provide a text comment that describes the plant population and how the polygon was mapped (i.e. polygon created from three waypoints). Rare aquatic plants observed during a meandered search are often best documented with a polygon, particularly if multiple plants were observed or the population covered an extensive area, and the extent of the population is known.

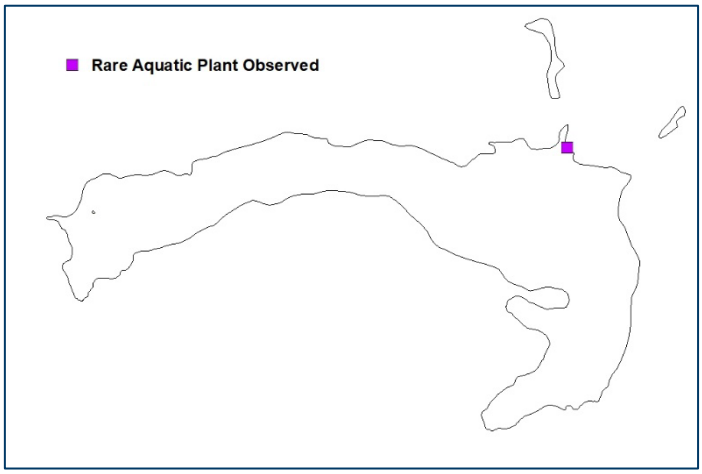
3) Confidence of the Extent of Rare Aquatic Plant Population

- Surveyors reporting sites of rare aquatic plants will also be asked to provide information on the confidence of the mapped observation of the rare plant.
    - Confident Full Extent of Observation is Not Known: This category is appropriate if no information was collected on the plant population or if only a portion of suitable habitat was searched. This category might also be used when a surveyor visits a single site on a lake (such as a public water access) and locates a rare plant; they have no information on the potential occurrence of the plant elsewhere in the lake.
    - Uncertain if Full Extent of Observation is Known: This category indicates uncertainty around the extent of the population in relation to the specific observation. Some information is known about the rare aquatic plant population, but more information is needed to assess the full extent of the population. For aquatic plant surveys, this category may be most appropriate when rare plants are located during a systematic survey. For example, if a rare plant is observed at some sample stations during a lakewide point intercept survey, the surveyor has some confidence that a large portion of the potential habitat has been searched and they can provide an estimate of the distribution of the rare plant within that lake. However, "uncertain" indicates that there are still large littoral areas that were not searched.
    - Confident Full Extent of Observation is Known: This category is used when the surveyor is confident they have searched through all suitable habitat within the area and that search conditions were conducive to locate the plant (good weather, good water clarity, appropriate time of year). If, for example, a rare plant is found on a high percentage of sites in a lakewide point intercept survey, the surveyor may be confident in stating that the plant population extends along a specific shoreline and within a specific depth range. Surveyors may be more confident in reporting population extents for emergent and floating rare aquatic plants than for submerged plants where detection is more difficult.

Example 1. Student interns collected and unknown plant and recorded GPS location at collection site. Plant later determined to be a rare species.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Search effort was limited to actual point of collection

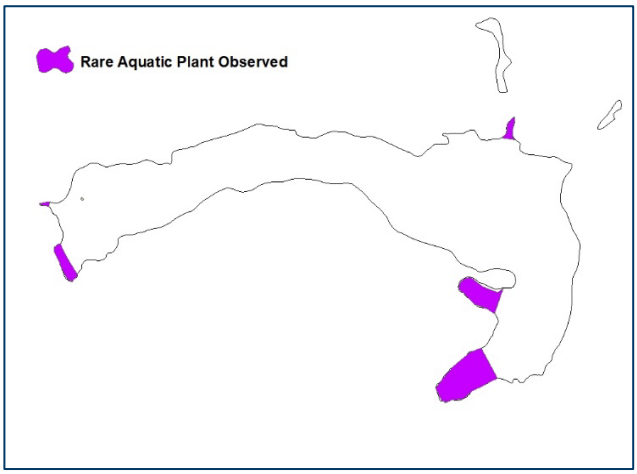
Figure 9-1 Rare plant observation example 1.



Example 2. Surveyor with plant identification experience locates rare plant during a targeted meandered search for that species in suitable habitat. Surveyor is confident, based on their knowledge and search effort, that there are no unmapped areas of the rare plant.

Observation Type: Voucher Specimen
GIS File Type: Polygon
Population Extent: Confident Known
Comments: Entire littoral area searched and rare plant only found in protected bays adjacent to undeveloped shores.

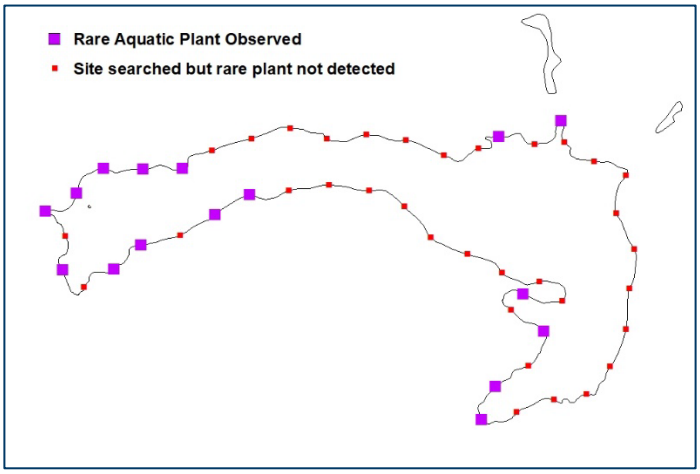
Figure 9-2 Rare plant observation example 2.



Example 3. Surveyor with plant identification experience surveys nearshore plots around entire lake and locates rare species on numerous sites.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Entire shoreline was included in survey and rare plant was located on 16 of 50 sites but 200 meter stretches between sites were not searched and deep water zone was not searched.

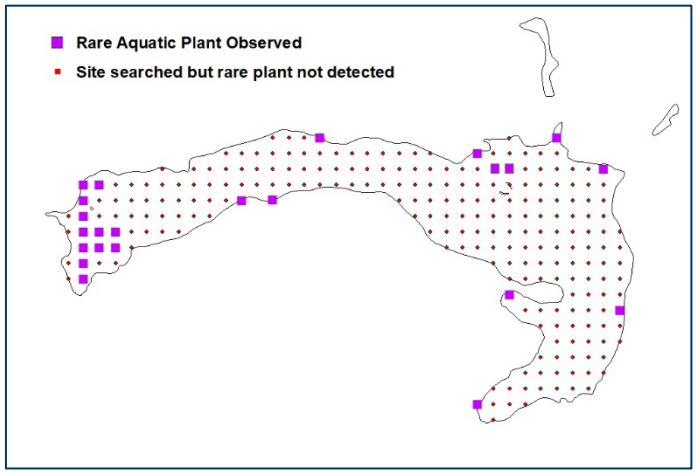
Figure 9-3 Rare plant observation example 3.



Example 4. Surveyors with plant identification experience collect submerged rare plant on multiple sites during a lakewide point intercept survey. Area between survey stations may be suitable habitat but is not searched. It is likely that there are unmapped areas of the rare plant.

Observation Type: Voucher Specimen
GIS File Type: Point
Population Extent: Confident Not Known
Comments: Entire lake was included in survey and rare plant was located on 23 of 243 sites but 80 meter stretches between survey sites were not searched.

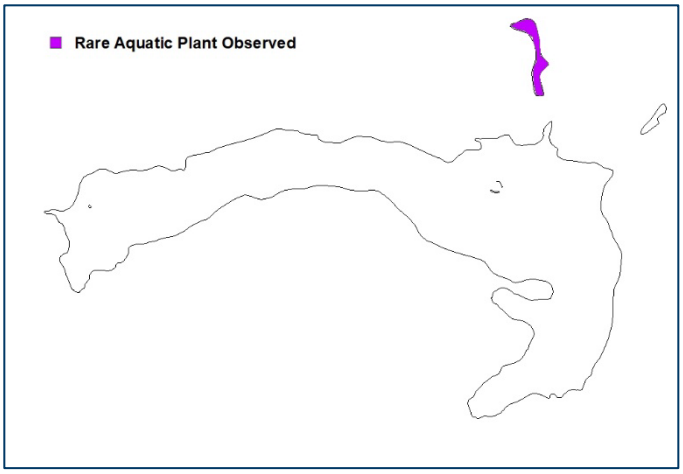
Figure 9-4 Rare plant observation example 4.



Example 5. Surveyors with plant identification experience view rare plant in flower from a distance and cannot physically access site to collect voucher specimen. Surveyors observe that plant extends across entire basin.

Observation Type: Photo
GIS File Type: Polygon
Population Extent: Confident Known
Comments: Observed from road that flowering plants present across entire basin.

Figure 9-5 Rare plant observation example 5.



Chapter 11 Collection, Preservation, and Photographic Documentation of Aquatic Plant Specimens

Objectives

Collecting aquatic plant specimens for laboratory analysis, herbaria submission, and/or identification verification can be challenging because aquatic plants can quickly dry, change in appearance, and die when removed from lake water. This chapter standardizes the collection, preservation, and photographic documentation of aquatic plant specimens to help ensure the following:

b. Plants are collected when appropriate
c. Plants are correctly identified
d. Live or preserved plant material can be accepted in collaborative research projects
e. Museum quality specimens are properly preserved

Introduction

The most common reason to collect aquatic plants during surveys is to verify taxonomic identification. Aquatic plant identification can be challenging, and surveyors may not always be confidently able to identify a plant to the species level. Additionally, plant classification is constantly changing. Voucher specimens can be examined to verify the identity of plants located during surveys and can be used to cross-reference these changes to previous studies. Plants may also be collected to document new locations of rare plants, new county or state records, and for a variety of research projects. The types of plant collection associated with MNDNR lake surveys include:

- Live plant collection for immediate identification
- Low quality preserved specimen for identification
- Museum quality preserved voucher collection
- Live plant collection for use in a research project, such as genetic analysis.

A voucher herbarium specimen is a pressed plant specimen deposited in a recognized herbarium which is typically associated with a university or research organization. Herbarium specimens serve many purposes which can include some of the following: to aid botanists in plant identification; to serve as subjects in morphological, systematic and genetic studies (Carter 2009, Espinosa and Pinedo 2018); to

study phenology and ecological responses to climate change (Calinger et al. 2013; Everill et al. 2014); and even to study herbivory trends (Beaulieu et al. 2019) and catalog organisms that may be present on collected specimens. As more herbaria digitize collections and make them available online, researchers can more quickly access and analyze data from massive numbers of specimens covering broad geographic and temporal ranges (Park 2012, Primack and Gallinat 2017).

Surveyors may often collect low quality specimens during surveys because plants may not be fully mature (with flowers or fruit) and only a portion of the plant may be collected on a sample rake. Even if they will not be permanently retained in an herbarium, the collection methods are the same as high quality specimens.

Surveyors should also be prepared to properly collect and transport aquatic plant specimens. This includes taking precautions to prevent the spread of non-native organisms to new locations. If correctly processed, live specimens of most taxa can remain viable for at least a week. If longer term preservation of the specimen is required, the specific steps depend on the plant type and the intended use of the plant sample.

LEU and MBS provide annual workshops on aquatic plant identification. Techniques to collect and preserve specimens are included. Staff in these programs can provide additional technical assistance on plant identification on request.

Collecting Aquatic Plants

Permits

Obtain all necessary access permissions and permits prior to collecting. This may include:

- General permit to transport aquatic plants and lake water
- General permit for herbarium specimens of prohibited species Permit for herbarium AIS specimens
- Permit to collect rare species
- Permit(s) to collect in State Parks and/or other jurisdictions

When to collect

Plant collections for herbarium vouchers should be collected during plant maturity when feasible. Ideally, plant reproductive structures (flowers or fruits in vascular plants; gametangia in non-vascular plants from the Characeae Family) should be included. For heterophyllous plants (Fig 2-6), all leaf types present (submerged, floating, emergent) should be included. Roots and rhizomes can be important in identification, particularly for most emergent plants such as bulrushes (*Schoenoplectus*), sedges (*Carex*) and spikerushes (*Eleocharis*). Multiple trips may be needed to locate and collect plants in their entirety.

That said, for some unique species, if the only available specimen is immature or lacking reproductive structures, it may still be worth collecting to document the species occurrence.

How to collect

When collecting plants for identification purposes, the goal is to collect enough plant material for more detailed observation in the office and/or by an experienced botanist. It is important to collect the appropriate plant parts and transport them in a manner that retains their integrity (a dried mass of plants is not easily identified).

The general guidelines for aquatic plant collection include the following:

- Collect plant by hand when feasible. Collecting single individual plants is recommended (as opposed to rake tines of tangled stems or branchlets).
- Collect sufficient plant material to meet identification, voucher, or research needs. If collecting as part of a collaborative project where multiple collections are needed, all material collected from a site is considered as the same collection. Collections from a different geographic location on the lake, or on a different date, are considered unique collections.
- Gently rinse plants in lake water to remove excess substrate, phytoplankton, and calcium deposits. A plastic tray and a plastic squirt bottle can be used to help rinse at the lake.
- Place each plant taxon collected in a unique collection bag to help ensure that plant fragments remain with the parent plant.
- Label each bag and collect associated notes (see detailed collecting notes below).
- Dispose of all water and unused plant material according to MNDNR protocols to prevent spread of non-native species.

Collecting protocols also depend on the type of plant and should be adjusted as follows:

Vascular plants

- Ziploc bags work well for transporting and temporarily storing plants.
- If plants will be stored for several days, remove most of the lake water from the bag, blow into bag to add carbon dioxide (this reduces bacterial growth), and refrigerate.
- If plants will remain in extreme heat for an extended period, place stored plants in a cooler with ice packs.

Macroalgae (Characeae Family)

These plants can be more fragile than vascular plants and extra care must be taken to minimize damage to key diagnostic features. The goal is to transport live plants to an office or laboratory where they can

be examined under a microscope, used in genetic analyses research, and pressed and preserved as herbarium mounts.

- Whirl-pak bags should be used to transport and temporarily store specimens.
- Use lake water to fill whirl-pak to bottom of white line (about 2/3rds full).
- Place only a few individual plants in each whirl-pak bag.
- Grasp each wire end of the bag and twirl quickly until the bag is tightly sealed. Twist the wire ends together to secure the twirled bag. This should result in a large air pocket at the top of the bag that provides a protective cushion for the plants while transporting.
- Protect from sun while in the field; place bags in a shaded area such as inside a cooler (no ice).
- ***DO NOT REFRIGERATE! DO NOT ADD ICE!***

If collecting Characeae as part of the MNDNR collaborative research project with The New York Botanical Garden (contact Donna Perleberg for more information):

- Collect plants in triplicate – one sample per bag.
- Label each whirl-pak bag.
- Place the 3 whirl-pak bags into one labeled gallon Ziploc bag.
- Live specimens can be shipped via FedEx or other carrier, but overnight delivery is recommended.

Mosses (bryophytes)

- Use a 2 lb brown paper bag (never plastic) to store collected samples in the field (Janssens 2007).
- Collect only enough to fill the bottom of the bag with a single layer of stems.
- Keep freshly collected samples in a large mesh laundry or burlap bag so they have adequate circulation until they can be dried properly.

Collecting equipment

- Field notebook or iPad to record collection information
- GPS
- Permanent marker
- Labels on Waterproof paper (if not marking outside of bag)
- View tube (Figure A3) or snorkel and mask
- Hand lens
- Garden rake (Figure A1) or grappling hook
- Small shovel to collect roots of emergent plants

- Plastic tray to float and rinse plants
- Plastic squirt bottle to rinse plants
- Ziploc bags (assortment of quart and gallon size)
- Whirl-pak bags (18 oz., 4.5”x 9”, write-on)
- 2 lb brown paper bags (for aquatic mosses)
- Cooler (with ice for vascular plants; no ice for macroalgae)

Collection information

An example herbarium label is provided (Figure 10-1). The minimum required information for each collection includes:

- Scientific name
- Site location – a georeferenced location; latitude/longitude is preferred by most herbaria. UTM coordinates can be converted using online calculators such as geoplaner
- Lake name, county and MNDNR Lake Identification number
- Collector name
- Collection date

Additional information such as associated plant taxa, water depth, substrate type and plant abundance can also be included on the label to help inform statewide information on the habitat of the species.

If you collect more than a few specimens per year, it is also useful to assign a unique collection number to each plant collection and include it on the label. Some collectors assign a number in chronological order as they collect such as the following:

> Coll. #CLM95 (represents the 95th collection made by Courtney L. Millaway)

An alternative is to assign a collection number based on the survey date and total number of collections made that date such as the following:

> Coll. #DJP2018.0822-28 (represents the 28th collection made on August 22, 2018 by Donna J. Perleberg)

Labels should be printed on acid-free archival paper, cut out, and included with each specimen inside the newsprint once the specimen is properly dried. (For bryophytes, attach label to outside of paper bag). If submitting the specimen to an herbarium, refer to the institution’s specific guidelines for specimen collection and submission.

Preserving aquatic plants

Pressing vascular plants and macroalgae for herbarium mounts

Most aquatic plants can be preserved for long term storage by pressing in a plant press (a primary exception is aquatic mosses which should not be pressed). A wood frame plant press can be purchased or constructed (two pieces of wood, 11”x 16” x1/4”). Plant specimens and a label (or collection number) are placed in newsprint to separate individual collections. Each specimen is then layered between two pieces of blotter paper and then with a piece of corrugated cardboard on top and bottom. The blotter paper absorbs water, and the cardboard provides vents for aeration. Repeat layering with each additional specimen. Stacks of pressed specimens (with blotters and cardboard) are placed between the wooden herbarium press and the press can be tightened with straps (Figure 10-2).

Time and care should be taken to make create quality specimens. For most specimens, it is best to press material immediately upon collection. For some species of Characeae, pressing the plants in the boat or at the lake is the best way to keep branchlets intact.

Plant arrangement on herbarium sheet

Arrange plants in a way that leaves an open space in the lower right-hand corner of the herbarium sheet for a specimen label. Arrange plants carefully to maximize preservation of diagnostic features. Spread out leaves, flowers and fruits to avoid overlap and so they can be observed from different angles. Plants with stems taller than the herbarium sheet can be folded in a “V” or “W” shape. Plant parts, including seeds, that detach from the specimen can be placed in a small fragment envelope, labeled and included with the specimen.

Most emergent and some submerged plants can be arranged, pressed and dried directly between newspaper sheets. For many submerged plants, however, leaves and other structures need to be “floated” onto paper to facilitate separation of plant features to a more natural, non-collapsed form:

- Place plant on archival paper in a tray of water and arrange features
- Jointly lift paper and plant from water, allowing water to drain from bottom of paper

Alternatively, a plastic squirt bottle can be used to add water onto the paper to separate leaves and other plant parts. Parchment paper or wax paper can be placed on top of plants to prevent the plant specimen from adhering to the newspaper. This is particularly important for macroalgae (Characeae Family), *Brasenia* (watershield), *Utricularia* (bladderwort), *Myriophyllum* (water milfoil) and other fine-leaved submerged plants.

Pressing and drying plants

Do not overtighten or place heavy weights on the press as this will break plant cells, particularly in Characeae. The plant press should be checked daily to replace wet blotters with dry blotters. Dried specimens should be stored in an airtight plastic box or herbarium cabinet to prevent insect damage. Do not use a microwave to dry plants and do not use a heated drier for Characeae specimens; both can result in cell damage that prevents DNA analysis and may hinder morphological analysis.

Pressing equipment

- Plastic tray
- Squirt bottle for water
- Archival (100% cotton) paper (8”x11”) for Characeae
- Archival (100% cotton) paper (11.5’’x16.5’’) for vascular plants
- Parchment or wax paper (place directly over Characeae specimens and vascular specimens that may stick to newsprint)
- Newsprint
- Blotters (12”x18”)
- Cardboard ventilators (12”x18”)
- Plant press (or 2 pieces of plywood approx. 12”x18”x14”)
- Pencil (for writing collection number on newsprint or herbarium sheet)

Preservation of aquatic mosses

Aquatic mosses should not be pressed. The preferred method of preservation is to dry the plants within the paper collection bag (Janssens 2007).

- Remove excess substrate if present to prevent abrasion to plant
- Label paper bag with collection number and date
- Dry plants in the paper collection bag in front of a fan or in a plant dryer at 60°C

Photographic documentation of plants

When not to collect plant vouchers

In some unique situations it may not be possible or wise to collect and preserve live plant material to document a species. In these situations, good quality photographs may be helpful to verify the species’ identity and document its occurrence.

If a plant population appears to be small with only a few individuals present, surveyors should consider whether collecting a voucher specimen may harm the population. This is a particular concern for rare species. Fortunately, most submerged aquatic plant species that are listed as rare are often found to be locally abundant.

In Minnesota, collecting plants in State Parks, National Forests and many other municipal parks is prohibited. Special permits can be obtained for scientific surveys and rare plant collection, but these must be obtained in advance.

Finally, surveyors may encounter situations where they can visually see a plant but cannot safely or legally access the site to make a collection. In all these situations, photographs may be the most appropriate means to verify the plant's identity and document its occurrence.

Taking photographs to aid in plant identification and documentation

Photographs are most useful for plants that can be identified using macroscopic features such as flower color and leaf arrangement. Tips for taking good quality photographs to aid in plant identification include the following:

- If possible, take photographs of the plant as you encountered it at the site. (Is it growing as an emergent? Matted to the surface?). Try to include photographs of the entire plant as well as close-up photographs of key features.
- If tangled with other plants, gently separate and photograph the individual plant on its own
- Include an item in the photograph for scale (i.e. ruler, coin)
- For submerged aquatic plants, photograph the plant in a tray of water or against a solid color background
- If present, photograph plant parts that may be diagnostic (flowers, fruit, leaf arrangement, leaf veins)
- If using a digital camera, turn on "location" to obtain a dated, georeferenced photograph

Data management

Herbarium specimens collected by LEU are entered in a FileMaker database; MBS enters collection data in a Microsoft Access database. These databases are used to create herbarium labels and to export required data to herbaria. Minnesota aquatic plant specimens collected by MNDNR are primarily deposited at the University of Minnesota Bell Museum and New York Botanical Garden. These herbaria have online websites where digital images of specimens can be viewed and data on species collections can be downloaded.

Figure 10-1 Example herbarium label

Aquatic Plants of Minnesota, U.S.A.
CERATOPHYLLACEAE
Ceratophyllum demersum L.

Lake: Elephant ID:69081000 St. Louis County, MN
Latitude 48.18410 Longitude -92.733206
southeast bay. Substrate: muck; Depth: 6 ft

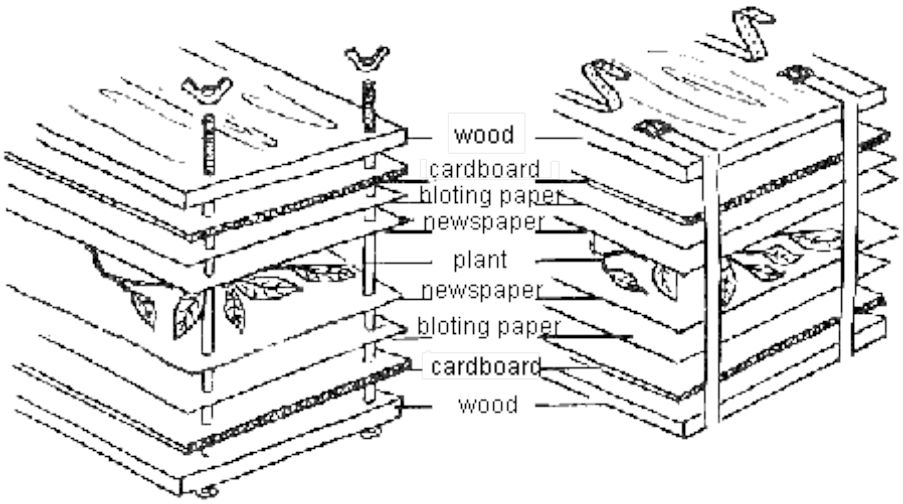
Associates: *Nymphaea odorata, Nuphar variegata, Potamogeton epihydrus, P. zosteriformis, Myriophyllum sibiricum*

Donna J. Perleberg
Coll. #DJP2018.0822-28

August 22, 2018 DNR Permit #23218
Minnesota Department of Natural Resources

Figure 10-2 Herbarium press components

(Source: American Museum of Natural History)



[How to press and preserve plants]

References

Aaseng, N.E., J.C. Almendinger, R.P. Dana, D.S. Hanson, M.D. Lee, E.R. Rowe, K.A. Rusterholz and D.S. Wovcha. 2011. Minnesota's native plant community classification: A statewide classification of terrestrial and wetland vegetation based on numerical analysis of plot data. Biological Report No. 108. Minnesota County Biological Survey, Ecological Land Classification Program, and Natural Heritage and Nongame Research Program. Minnesota Department of Natural Resources. St. Paul.

Ahrenstorff, T.D., G.G. Sass and M.R. Helmus. 2009. The influence of littoral zone coarse woody habitat on home range size, spatial distribution, and feeding ecology of largemouth bass (*Micropterus salmoides*). Hydrobiologia. 623:223-233.

Beaulieu C, Lavoie C, Proulx R. 2018 Bookkeeping of insect herbivory trends in herbarium specimens of purple loosestrife (*Lythrum salicaria*). Phil. Trans. R. Soc. B 374: 20170398.

Braun-Blanquet, J. 1965. Plant sociology; the study of plant communities. (Transl. rev. and ed. by C.D. Fuller and H.S. Conard). Hafner, London.

Calinger K.M., S. Queenborough, P.S. Curtis. 2013. Herbarium specimens reveal the footprint of climate change on flowering trends across north-central North America. Ecology Letters. 16:1037–1044.

Caratti, J.F. 2006. Point Intercept (PO). IN: Lutes, D.C., R.E. Keane, J.F. Caratti, C.H. Key, N.C. Benson, S. Sutherland, and L.J. Gangi. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station. P. PO-1-17.

Carter, R. 2009. Preparation and Use of Voucher Specimens for Documenting Research in Weed Science. Weed Technology. 21-1101-1108.

Cheal D. 2008. Repeatability of cover estimates? Ecological Management & Restoration 9(1): 67-68.

Christensen, D.L., B.R. Herwig, D.E. Schindler, and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications 6:1143–1149.

Crow, G.E. and C.B. Hellquist. 2000. Aquatic and wetland plants of Northeastern North America. 2 volumes. The University of Wisconsin Press, Madison.

Daubenmire. R.F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Daubenmire, R.F. 1968. Plant communities; a textbook of plant synecology. Harper and Row. NY. 300 pp.

Deppe, E.R. and R.C. Lathrop. 1992. A comparison of two rake sampling techniques for sampling aquatic macrophytes. In: Research Management Findings, Bureau of Research – Wisconsin Department of Natural Resources, No. 32, March 1992.

Downing J. A., M. R. Anderson. 1985. Estimating the standing biomass of aquatic macrophytes. Canadian Journal of Fisheries and Aquatic Sciences 42:1860-1869.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Science. Malden, Massachusetts. 360 pp.

Espinosa, F. and M. Pinedo. 2018. On the use of herbarium specimens for morphological and anatomical research. Botany Letters. 165:361-367.

Everill P.H., R.B. Primack, E.R. Ellwood, E.K. Melaas. 2014. Determining past leaf-out times of New England's deciduous forests from herbarium specimens. American Journal of Botany 101:1293–1300.

Francis, T.B. and D.E. Schindler. 2006. Degradation of littoral habitats by residential development: woody debris in lakes of the Pacific Northwest and Midwest, United States. Ambio 35: 274-280

Garrison, P.J., D.W. Marshall, L. Stermick-Thompson, P.L. Cicero and P.D. Dearlove. 2005. Effects of pier shading on littoral zone habitat and communities in Lakes Ripley and Rock, Jefferson County, Wisconsin. Wisconsin Department of Natural Resources. PUB-SS-1006 2005.

Goodall, D.W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Australian Journal of Scientific Research. Series B5:1-41.

Greig-Smith, P. 1983. Quantitative Plant Ecology. University of California Press, Berkeley, California, USA.

Hall, F.C. 2001. Photo point monitoring handbook: Part A - field procedures. Gen. Tech. Rep. PNW-GTR-526.Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 pp. 2 parts.

Harman, W. N., M. F. Albright and C.M. Snyder. 2008. Aquatic macrophyte management plan facilitation, Lake Moraine, Madison County, N.Y., 2007 Tech. Sept. #25. SUNY Oneonta Bio. Fld. Sta., Oneonta, NY.

Hatton, T.J., N.E. West and P.S. Johnson. 1986. Relationships of the error associated with ocular estimation and actual total cover. Journal of Range Management. 39(1):91-92.

Hauxwell, J. S. Knight, K. Wagner, A. Mikulyuk, M. Nault, M. Porzky, and S. Chase. 2010. Recommended baseline monitoring of aquatic plants in Wisconsin: sampling design, field and laboratory procedures, data entry and analysis, and applications. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010. Madison, Wisconsin, USA.

Heywood, J.S. and M.D. DeBacker. 2007. Optimal sampling designs for monitoring plant frequency. Rangeland Ecology and Management. 60(4): 426-434.

Indiana Department of Natural Resources. 2007. Tier II aquatic vegetation survey protocol. Indiana Department of Natural Resources, Division of Fish and Wildlife. Indianapolis, IN.

Janssens, J.A. 2007. Description of Bryophyte Assemblages of Mesohabitats. (available as PDF from the author, janss008@umn.edu).

Jennings, M.J., E.E. Emmons, G.R. Hatzenbeler, C. Edwards, and M.A. Bozek. 2003. Is littoral habitat affected by residential development and land use in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3) 272-279.

Jennings, M, D., Faber-Langendoen, R. Peet., et al. 2004. Guidelines for describing associations and alliances of the U.S. national vegetation classification. Version 3.0. Vegetation Classification Panel, Ecological Society of America. Washington, DC.

Jesson, R., and R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Game Investigational Report No. 6. Minnesota Department of Conservation, Division of Game and Fish, Section of Research and Planning, Fish and Wildlife Surveys Unit, St. Paul. 10 pp.

Johnson, J.A. and R.M. Newman. 2011. A comparison of two methods for sampling biomass of aquatic plants. Journal of Aquatic Plant Management 49:1-8.

Kershaw, K. 1966. Quantitative and dynamic ecology. Edward Arnold Ltd. London. 183 pp.

Knopik, J. and Simon, S. 2016. GIS Manual for MN DNR Lake Plant Surveys.

Kuchler, A.W. 1951. The relation between classifying and mapping vegetation. Ecology 32:275-283.

Maceina, M.J., Shireman, J.V., Langeland, K.A., and D.E. Canfield Jr. 1984. Prediction of submersed plant biomass by use of a recording fathometer. J. Aquat. Plant Manage. 22:35-38.

Madsen, J.D. 1993. Biomass techniques for monitoring and assessing control of aquatic vegetation. Lake and Reservoir Management. 7: 141-154.

Madsen J.D. and J.A. Bloomfield. 1993. Aquatic vegetation quantification symposium: an overview. Lake and Reservoir Management 7:137-140.

Madsen, J.D. 1999. Point intercept and line intercept methods for aquatic plant management. *APCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Madsen, J.D. and R.M. Wersal. 2012. A review of aquatic plant monitoring and assessment methods. Geosystems Research Institute, Mississippi State Univ. A report for Aquatic Ecosystem Restoration Foundation.

Maceina, M. J. and J. V. Shireman. 1980. The use of a recording fathometer for determination of distribution and biomass of hydrilla. Journal of Aquatic Plant Management 18:34-39.

Manley, P.N., B. Van Horne, J.K. Roth, W.J. Zielinski, M.M. McKenzie, T.J. Weller, F.W. Weckerly and C. Vojta. 2006. Multiple species inventory and monitoring technical guide. Gen. Tech. Rep. WO-73., U.S. Department of Agriculture, Forest Service, Washington D.C. 204 pp.

Marburg, A.E., M.G. Turner, and T.K. Kratz. 2006. Natural and anthropogenic variation in coarse wood among and within lakes. Journal of Ecology 94:558–568.

Mikulyuk, A., J. Hauxwell, P. Rasmussen, S. Knight, K.I. Wagner, M.E. Nault and D. Ridgely. 2010. Testing a methodology for assessing plant communities in temperate inland lakes. Lake and Reservoir Management 26:54-62.

Minnesota Department of Natural Resources. 1993. Lake Survey Manual. Section of Fisheries, St. Paul.

Minnesota Department of Natural Resources. 2003. Field Guide to the native plant communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, St. Paul.

Minnesota Department of Natural Resources. 2005. Aquatic vegetation mapping guidelines (working version). Minnesota Department of Natural Resources. Section of Fisheries. St. Paul.

Minnesota Department of Natural Resources, Division of Ecological Resources. 2008. Rare Species Guide: An online encyclopedia of Minnesota's rare native plants and animals. Minnesota Department of Natural Resources, St. Paul, Minnesota. www.dnr.state.mn.us/rsg. Accessed 20 December 2018.

Minnesota Department of Natural Resources 2011. Shallow Lakes Program Intern Handbook. Minnesota Dept. Of Natural Resources. Shallow Lakes Program. Brainerd, MN.

Minnesota Department of Natural Resources. 2019. Division of Ecological Resources, Minnesota Biological Survey. Procedures: Rare Plant Surveys. Minnesota Department of Natural Resources, St. Paul, Minnesota. Rare plant survey procedures. Accessed 04 January 2019.

MNTaxa. 2013. Minnesota State checklist of vascular plants. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, St. Paul. Minnesota state checklist of vascular plants Accessed 04 January 2019.

Moyle, J.B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. American Midland Naturalist 34:402-420.

Myhre, K.M. 1998. Method Used in Creating Species Lists for Lakes. Minnesota Department of Natural Resources. Minnesota County Biological Survey Unit.

Newman, R.M. and K. Holmberg, J. Foley, D. Middleton. 1998. Assessing macrophytes in Minnesota's game lakes. Final Report to the Minnesota Dept. of Natural Resources, Wetland Wildlife Populations and Research Group, Bemidji. 69 pp.

Nichols, S.A. 1984. Quantitative methods for assessing macrophyte vegetation. In: Ecological assessment of macrophyton: collection, use, and meaning of data. ASTM STP 843. W.M. Dennis and B.G. Isom, eds. American Society for Testing and Materials. pp. 7–15.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Lake and Reservoir Management 15(2):133–141.

Park, G.N. 1972. Point height intercept analysis a refinement of point analysis for structural quantification of low arboreal vegetation. New Zealand Journal of Botany. 11(1): 103-114.

Park, I.W. 2012. Digital herbarium archives as a spatially extensive, taxonomically discriminate phenological record; a comparison to MODIS satellite imagery. International Journal of Biometeorology. 56: 1179−1182.

Perleberg, D.J. 2001a. Evaluation of DNR Fisheries Lake Vegetation Survey Method. Unpublished report. Minnesota Department of Natural Resources, Ecological Services Division, Brainerd. 32 pp.

Perleberg, D.J. 2001b. Estimating species abundance and distribution: a comparison of three quantitative survey methods for lakewide assessment of submerged macrophyte communities. Unpublished report. Minnesota Department of Natural Resources, Ecological Services Division, Brainerd. 13 pp.

Perleberg, D., P. Radomski, and S. Simon. 2012. Score Your Shore: citizen shoreline description survey. Version 2. Minnesota Department of Natural Resources. Division of Ecological and Water Resources. Lakes and Rivers Program. Brainerd, MN 56401.

Primack, R. and A.S. Gallinat. 2017. Insights into grass phenology from herbarium specimens. New Phytologist. 213: 1567-1568.

Radomski, P. and T. Goeman. 2001. Consequences of human lakeshore development on emergent and floating-leaf vegetation abundance. North American Journal of Fisheries Management 21:46-61.

Radomski, P., K. Woizeschke, K. Carlson and D. Perleberg, D. 2011. Reproducibility of emergent plant mapping on lakes. North American Journal of Fisheries Management 31 (1) 144-150.

Radomski, P. and D. Perleberg. 2012. Application of a versatile aquatic macrophyte integrity index for Minnesota lakes. Ecological Indicators 20:252-268.

Radomski, P. and B.V. Holbrook. 2015. A comparison of two hydroacoustic methods for estimating submerged macrophyte distribution and abundance: a cautionary note. Journal of Aquatic Plant Management 53:151-159.

Roth, B.M., I.C. Kaplan, G.G. Sass, P.T. Johnson, A.E. Marburg, A.C. Yannarell, T.D. Havlicek, T.V. Willis, M.G. Tuner, and S.R. Carpenter. 2007. Linking terrestrial and aquatic ecosystems: the role of woody habitat in lake food webs. Ecological Modelling 203:439-452.

Sabol, B. M., R. E. Melton Jr., R. Chamberlain, R., P. Doering, and K. Haunert. 2002. Evaluation of a digital echo sounder system for detection of submersed aquatic vegetation. Estuaries 25:133–141.

Sass, G.G., J.F. Kitchell, S.R. Carpenter, T.R., Hrabik, A.E. Marburg, and M.G. Turner. 2006. Fish community and food web responses to a whole-lake removal of coarse woody habitat. Fisheries 31:321–330.

Sass, G.G., S.R. Carpenter, J.W. Gaeta, J. F. Kitchell, and T.D. Ahrenstorff. 2012. Whole-lake addition of coarse woody habitat: response of fish populations. Aquatic Sciences - Research across Boundaries 74:255–266.

Sass, G.G., S.L. Shaw, C.C. Grenstermacher, A.P. Porreca, and J.J. Parkos III. 2023. Structural habitat in lakes and reservoirs: physical and biological considerations for implementation. North American Journal of Fisheries Management 43:290–303.

Simmonds, J., and D. MacLennan. 2005. Fisheries Acoustics: Theory and Practice, 2nd edition. Blackwell Science, Oxford.

Spencer D.F. and L.C. Whitehand. 1993. Experimental design and analysis in field studies of aquatic vegetation. Lake and Reservoir Management. 7:165-174.

Thomas, G. L., S. L. Thiesfeld, S. A. Bonar, R. N. Crittenden, and G. B. Pauley. 1990. Estimation of submergent plant bed biovolume using acoustic range information. Canadian Journal of Fisheries and Aquatic Sciences 47: 805-812.

Valley, R. D., and M. T. Drake, 2007. What does resiliency of a clear-water state in lakes mean for the spatial heterogeneity of macrophytes? Aquatic Botany 87: 307–319.

Wetzel, R.G., 2001. Limnology, Lake and River Ecosystems. 3rd ed. Academic Press, New York.

Whittaker, R.H. (ed). 1978. Classification of Plant Communities. Junk Publishers, The Hague, Boston. 408 pp.

Whysong, G.L. and W.W. Brady. 1987. Frequency Sampling and Type II Errors. Journal of Range Management. 40(5): 472-474.

Williams, L.D., G.O. Dick, R.M. Smart, and C.S. Owens. 2008. Point-intercept and surface observation GPS (SOG): A comparison of survey methods-Lake Gaston, NC/NV. ERDC/TN APCRP-EA-019. U.S Army Engineer Research and Development Center, Vicksburg, MS.

Wisconsin Department of Natural Resources. 2008. Wisconsin's critical habitat designation manual: a comprehensive conservation strategy for identification of sensitive areas and public rights features in Wisconsin lakes. Madison, WI.

Wisconsin Department of Natural Resources. 2020. Lake shoreland and shallow habitat monitoring field protocol. EGAD # 3400-2020-19. Madison, WI.

Xie, Y., Z. Sha, and M. Yu. 2008. Remote sensing imagery in vegetation mapping: a review. Journal of Plant Ecology 1: (1) 9-23.

Yin, Y., J.S. Winkelman and H.A. Langrehr. 2000. Long Term Resources Monitoring Program procedures: Aquatic vegetation monitoring. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, April 2000. LTRMP 95-P002-7. 8 pp + Appendices A-C.

Yin, Y. and R. Kreiling 2011. The evaluation of a rake method to quantify submersed vegetation in the Upper Mississippi River. Hydrobiologia. 675:187-15.

Glossary

Organization Abbreviations

Abbreviation	Definition
EWR	Ecological and Water Resources Division (within MNDNR)
LEU	Lake Ecology Unit (Unit within MNDNR – EWR)
MBS	Minnesota Biological Survey (Unit within MNDNR – EWR)
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency

Appendix A: Equipment Checklists and Photos

Table A1. Checklist of equipment

Chapter		3	4	5	6	7	8	9, 10
Survey Method		Score the Shore	Mapping Floating and Emergent Plant Stands	Transect	Point Intercept	Quantitative Nearshore	Hydroacoustics	Plant Collecting
Clipboard, pencils, permanent markers		X	X	X	X	X	X	X
Paper data forms: Lake contour map Aerial photograph of lake Survey station map		X	X	X	X	X	X	X
iPad	With Filemaker App				X	X		
	With Collector for GIS App	X	X					
Georeferenced camera		X						
GPS (and spare batteries)		X		X	X	X		X
Standard Depth finder		X	X	X	X	X		
Lowrance HDS depth finder with sonar							X	
SD card with microchip							X	
Sampling rake (double-headed attached to 30+ feet of rope)				X	X	X		X
8 feet pole marked in 1-foot increments				X	X	X		
View tube or snorkel				X	X	X		X
Plant field guides			X	X	X	X		X
Hand lens				X	X	X		X
Tray and wash bottle								X
Plant collecting bags								X

Figure A1. Double-headed, weighted garden rake for plant sampling



Figure A2. Using RAM mounts to secure electronic equipment to boat console



Figure A3. Commercially purchased View tube used to observe submerged vegetation



A “view tube” can be used to improve visual observation of submerged aquatic plants. The tube allows the surveyor to wade through shallow water and view plants as if they were snorkeling.

Commercially produced tubes are available from several outdoor product companies and range in prices from about $70 to $125.

A view tube can also be constructed from pvc pipe or a plastic bucket or trash bin by sealing one end with clear plexiglass. Handles and a foam or neoprene face cushion can be added.

For specific directions and materials to construct a view tube:

1. from pvc pipe: University of Wisconsin Extension Lakes, Steven Point, Wisconsin
   Aquascope directions

2. from a plastic bucket: State of Connecticut, Department of Energy and Environmental Protection
   How to make a clear bottom bucket

3. from a plastic trash bin: Reed, R.N., C.A. Young and R.T. Zappalorti. 2012. Snake Hibernacula and Communal Denning. Chapter 7. In: Reptile Biodiversity, Standard Methods for Inventory and Monitoring. Edited by Roy W. McDiarmid, Mercedes S. Foster, Craig Guyer, J. Whitfield Gibbons, and Neil Chernoff. University of California Press. 424 Pp.

Appendix B: Field Data Forms

1. Score the Shore Survey Form
2. Point-Intercept Survey Form
3. Near-Shore Plant Survey Form
4. Sample Plant Label

MNDNR SCORE THE SHORE SURVEY Survey Date: _____ pg ___ of ____

LAKE _____ Surveyors: _____

LAKE ID __ __ - __ __ __ __ - __ __

			Site Number															
LAND USE	Single-Family Residential																	
	Several Single-Family Residential Lots																	
	Multiple Dwelling Development																	
	Resort or Commercial Campground																	
	Other Commercial																	
	Agricultural																	
	Roadway																	
	Public Park																	
	Campsite																	
	Boat Access																	
	Undeveloped Nonwetland																	
	Undeveloped Wetland																	
SHORELAND	**Trees**	75-100																
		50-74																
		25-49																
		1-24																
		0																
	Shrubs	75-100																
		50-74																
		25-49																
		1-24																
		0																
	Natural Groundcover	75-100																
		50-74																
		25-49																
		1-24																
		0																
SHORELINE	**Trees / Shrubs or Wetland**	75-100																
		50-74																
		25-49																
		1-24																
		0																
	Natural Groundcover	75-100																
		50-74																
		25-49																
		1-24																
		0																
	overhead woody habitat (Y/N)																	
	Emergent and Floating-Leaf Cover	75-100																
		50-74																
		25-49																
		1-24																
		0																
AQUATIC	Man-made openings in plant beds (Y/N)																	
	downed woody habitat (Y/N)																	
	number of simple docks																	
	number of complex docks																	
	number of marinas																	
	number of lifts																	
	number of rafts or other																	

MNDNR Point-Intercept Survey	Survey Date: _____									pg ___ of ____
LAKE _____	Surveyors: _____									
LAKE ID __ __ - __ __ __ __ - __ __	**Site number**									
DEPTH (ft)										
substrate (BO, RB, GR, SA, SI, MR, MU)										
NO SURVEY - (**SH** = on shore, **D**= too deep)										
Abundance (0 = none, S = sparse, C = common, A = matted)										
PLANT SPECIES NAME										

MNDNR Near-Shore Plant Survey	Survey Date: _____								pg ___ of ____	
LAKE _____	Surveyors: _____									
LAKE ID __ __ - __ __ __ __ - __ __	**Site number**									
DEPTH (ft)										
substrate (BO, RB, GR, SA, SI, MR, MU)										
NO SURVEY - (**SH** = on shore, **D**= too deep)										
Abundance (0 = none, S = sparse, C = common, A = matted)										
PLANT SPECIES NAME										

Example Aquatic Plant Collection Form

MNDNR Aquatic Plant Collection Form

Plant Id: _____

County: _____ DOW: __ __ - __ __ __ __ - __ __

Lake: _____

GPS (Zone 15 Nad 83) N: __ __ __ __ __ __ __E: __ __ __ __ __ __

Depth zone ____ to ____ feet Substrate _____

Collector(s) _____

Area Office _____

Phone _____

Date: __ __ / __ __ / ____

Field
Notes_____

Example Aquatic Plant Collection Form

MNDNR Aquatic Plant Collection Form

Appendix C: Score the Shore training guides

Contents

Land Use Classes – description and images

Dock Types – descriptions and images

Score The Shore: Land Use Classes

Only one development class is recorded for each developed site. If more than one type of development occurs at a site, select the class that occupies most of the site.

SINGLE-FAMILY RESIDENTIAL

one permanent living structure entirely or partly within survey site



One house entirely within survey site



One house entirely within survey site



Boat house with living quarters



Boat house with living quarters



One home with multiple structures



Trailer house

SINGLE-FAMILY RESIDENTIAL

one permanent living structure entirely or partly within survey site



This site is classified as Single-Family because development (garage) extends into site even though house is outside of site boundaries.



House is hidden but evidence of development includes staircase and garden. May need to review aerial photograph to confirm presence of house.

SEVERAL SINGLE-FAMILY RESIDENTIAL

more than one permanent living structure entirely or partly within survey site









RESORT OR COMMERCIAL CAMPGROUND

May/may not include permanent structures (only developed sites within resort boundaries are classified as resort)





OTHER COMMERCIAL

(e.g., Restaurant, Marina, Hotel, School, etc.)





AGRICULTURAL

Includes pastureland and cropland. If house is present in site, classify as Single-Family Residential





ROADWAY

If house roadway is between lake and house, classify site as roadway. For example, if a road runs through a site and there is a house on the landward side of the road, record the site as “roadway” because most of the site is occupied by the road. If the house occurs between the road and the lake, record the site as “single-family residential”.





PUBLIC PARK

(e.g. ball field, hiking trails, picnic area, may or may not include permanent structures)









CAMPSITE

(may or may not include tent site or single camper)



Sites with mowed paths but no house are classified as campsite



BOAT ACCESS

With or without parking lot and/or dock



UNDEVELOPED – NON-WETLAND

Shoreline vegetation may be terrestrial or wetland but Shoreland vegetation is terrestrial





UNDEVELOPED – WETLAND





includes forested and unforested wetland

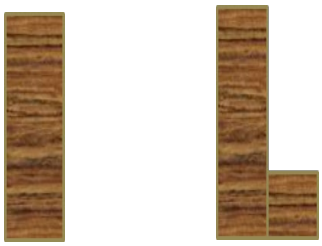




Score The Shore: Dock Types

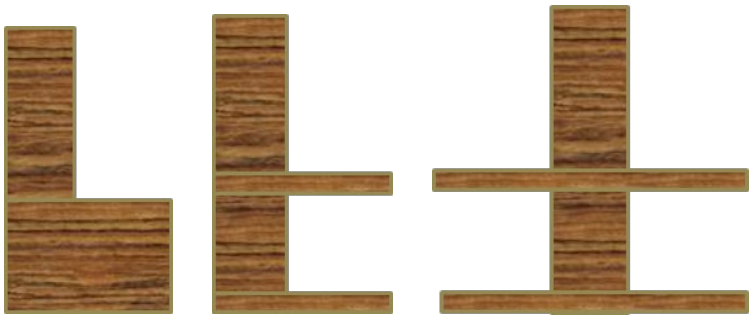
Simple dock

a straight or L-shaped dock; no platforms or slips



Complex dock

a dock that includes platforms and/or slips



Lift

a device for elevating boat above water surface; typically attached to a dock





Raft or other recreational objects

a platform that is anchored offshore and not connected to a dock; may be constructed of wood or other building materials or inflatable; and includes other recreational objects such as slides or trampolines





Marina

a dock with numerous slips that is associated with a commercial facility or multi-dwelling residence



Appendix D: Key to emergent and floating-leaf aquatic plant classes



I. **Emergent plants present in >50% of stand (polygon).** Floating-leaf plants may be absent or present in patches or throughout most of stand and may even cover a substantial portion of stand. Submerged plants may be present or absent. Areas of open water may be interspersed throughout the stand. Identify the most encountered emergent taxa; this will be considered the dominant taxa and will typically comprise more than 50% of the emergent plants. If a dominant emergent taxon cannot be identified, consider mapping the stand as two separate polygons.

- 2. Rush-like plants are the most frequently encountered emergent in stand and are distributed throughout the stand. Dominant taxa typically include bulrush (Schoenoplectus spp.) and/or spikerush (*Eleocharis* spp.). Broad-leaf emergent and/or floating-leaved plants may be present but do not dominate. Submerged plants may be present at any abundance level or may be absent. Sites are often comprised of hard substrates such as sand, gravel, and boulders but may include silt substrates; these are generally not highly organic sites.
  - 1. Broad-leaf emergent and floating-leaf plants are absent, or occur in less than 30% of bed…… Rushes Class
  - *dominant taxa may include:*
    a. Bulrush (*Schoenoplectus* spp.)
    b. Three-square bulrush (*Schoenoplectus pungens*)
    c. River bulrush (*Schoenoplectus fluviatile)*
    d. Spikerush (*Eleocharis* spp.)
  - 2. Broad-leaf (non-Rush) emergent plants and/or floating-leaf plants are present in 30% or more of stand…… Rushes & Others Class
- 2. Broad-leafed emergent plants (non-Rush) are the most frequently encountered plants in the stand and are distributed throughout the stand. Bulrush and/or spikerush may be present but do not dominate. Floating-leaved and/or submerged plants may be present at any abundance level or may be absent. Sites are often, but not always, comprised of soft substrates and may be high in organic content. *Identify dominant taxa:*
  1. Cattails (*Typha* spp.)……Cattail Class
     - *Dominant taxa may include:*
       a. Cattail (*Typha* spp.): Narrow-leaf cattail and broad-leaf cattail may both be present but it is difficult to identify plants to species and/or only a small portion of the stand can be assessed for species-level identification. Cattail stands identified through aerial photo interpretation should also be placed into general type.
       b. Narrow-leaf (*Typha angustifolia*) and/or hybrid (*T. x glauca*) dominate the stand and no areas of broad-leaf cattail are observed.
       c. Broad-leaf cattail (*Typha latifolia*).
  2. Broad-leaf (non-Cattail) emergent plants and/or floating-leaf plants are present in 30% or more of stand…… Cattails & Others Class

2. Wild rice (*Zizania* spp.)…….. go to **2a**
    a. Other emergent and floating-leaf plants are absent, or occur in less than 30% of bed…….Wild Rice Class
    b. Other emergent and/or floating-leaf plants are present in 30% or more of bed; floating-leaf plants may be present throughout stand…….Wild Rice & Others Class

- 2. Other emergent ……Other Emergent Class
    - *This class may be subdivided by dominant taxa, examples include:*
        a. arrowhead (*Sagittaria* spp.)
        b. common reed grass (*Phragmites australis*)
        c. pickerelweed (*Pontederia cordata*)
        d. horsetail (*Equisetum fluviatile*)
        e. sedge (*Carex* spp.)
    -

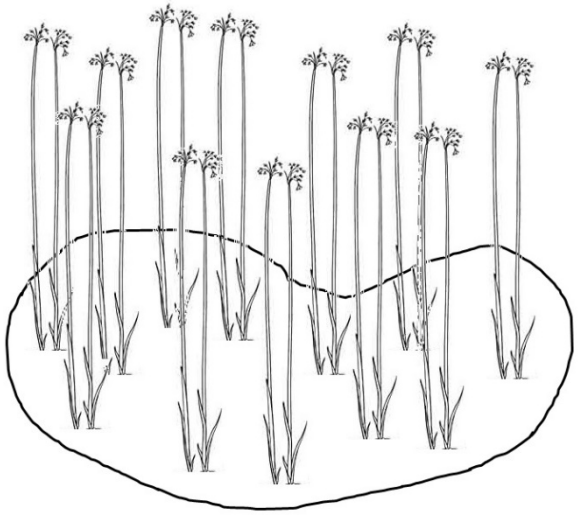
II. **Emergent plants present in <50% of stand (polygon).** Floating-leaf plants are present throughout most of stand often covering >50% of stand. Submerged plants may be present or absent. Areas of open water may be interspersed throughout the stand. Identify the most commonly encountered floating-leaf taxa; this will be considered the dominant taxa and will typically comprise more than 50% of the floating-leaf plants. If a dominant floating-leaf taxa cannot be identified, consider mapping the stand as two separate polygons. Identify the dominant taxa:

-
    A. Waterlilies (white waterlily or yellow waterlily)
        1. Other emergent and floating-leaf plants are absent, or occur in less than 30% of stand. Waterlily stands identified through aerial photo interpretation should be placed into this general class……Waterlily Class
            Dominant taxa may include:
            a. White waterlily (*Nymphaea* odorata)
            b. Yellow waterlily (*Nuphar variegata*)
            c. Both white and yellow waterlily
        -
        2. Other emergent and/or floating-leaf plants are present in 30% or more of bed……Waterlily and Others Class
        -
    B. Other floating-leaf plant……Other Floating-leaf Class

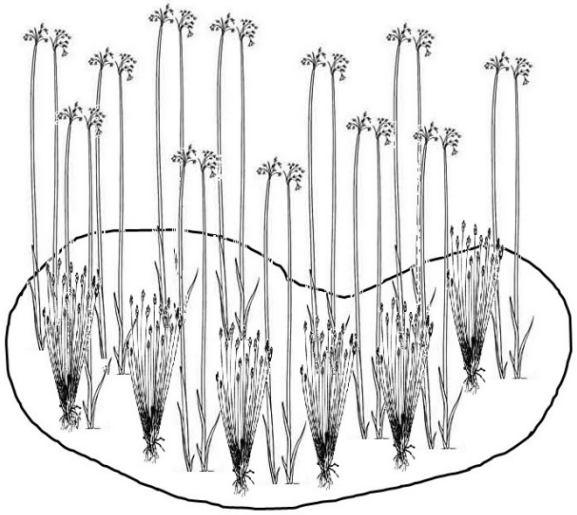
        This subclass may be subdivided by dominant taxa including:
        a. Watershield *(Brasenia schreberi*)
        b. Floating-leaf pondweed (*Potamogeton natans)*
        c. Floating-leaf bur *reed (Sparganium* spp.)
        d. Floating-leaf smartweed *(Persicaria amphibia)*

CLASS: RUSHES

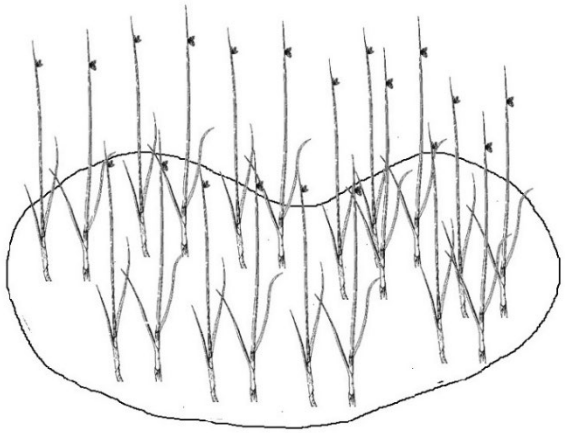
Bulrush



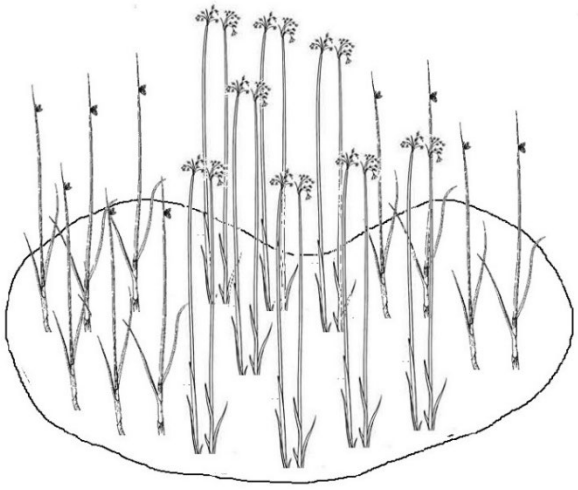
Bulrush-Spikerush



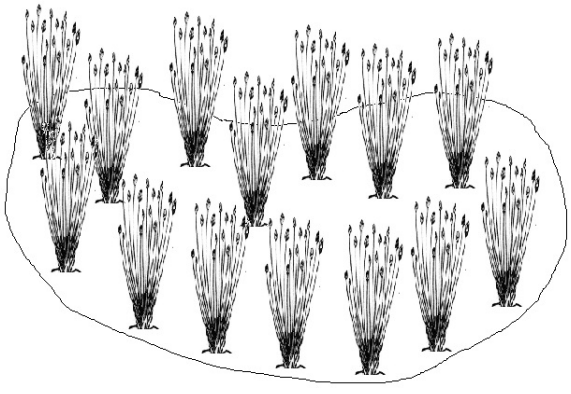
Three-square bulrush



Bulrush-Three-square bulrush



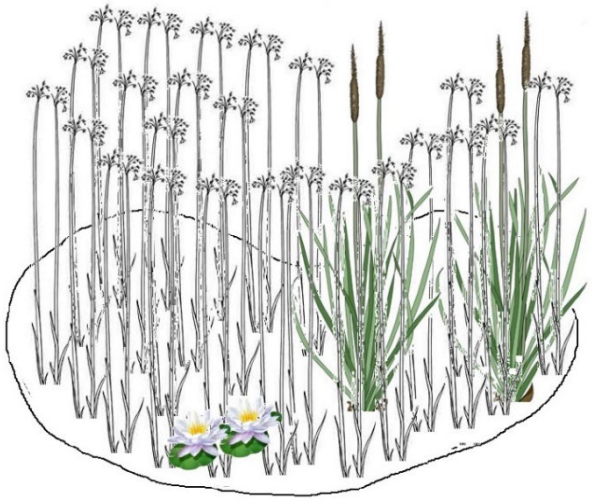
Spikerush



CLASS: RUSHES and Other (leafy plants)

Examples:

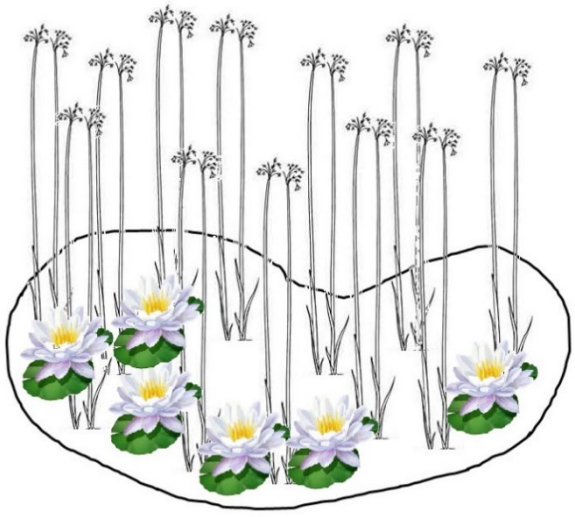
Bulrush – Cattail



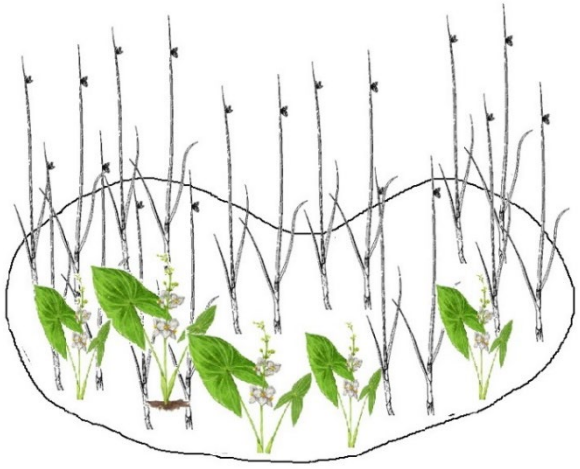
Bulrush – Wild rice



Bulrush – Waterlily



Three-square bulrush - Arrowhead



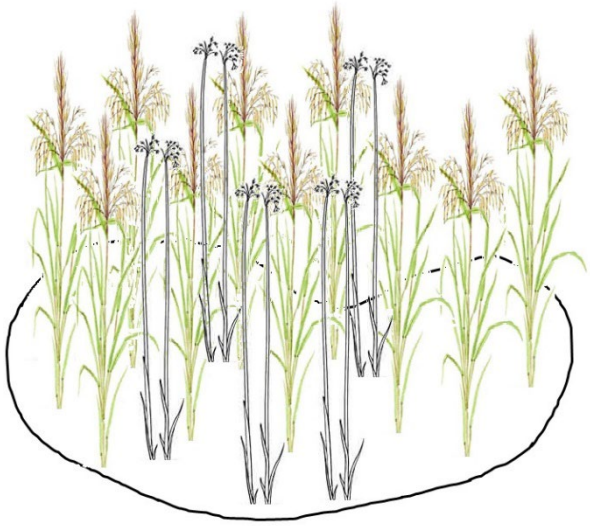
CLASS: Wild Rice

Wild rice

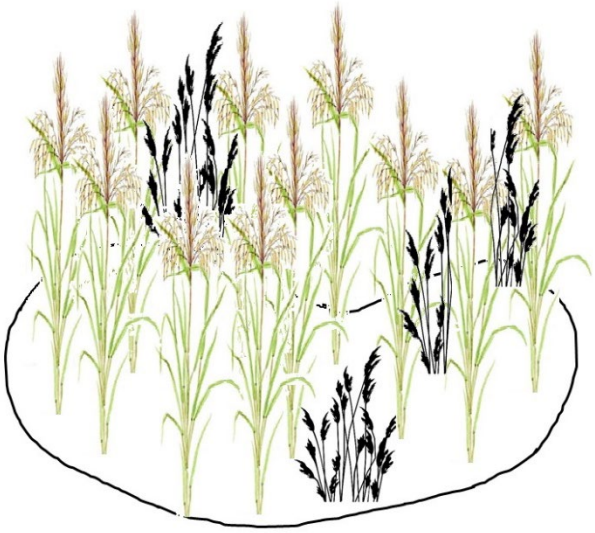


CLASS: Wild Rice & Other (Emergent/Floating)

Wild rice – Rush



Wild rice – Common reed grass



Wild rice – Waterlily

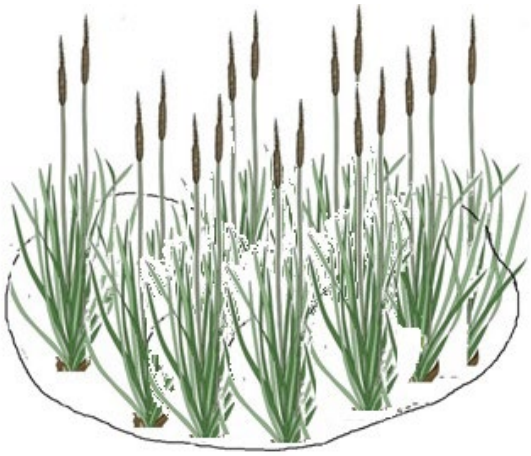


Wild rice – Waterlily



CLASS: Cattail

Cattails



Cattail-Arrowhead

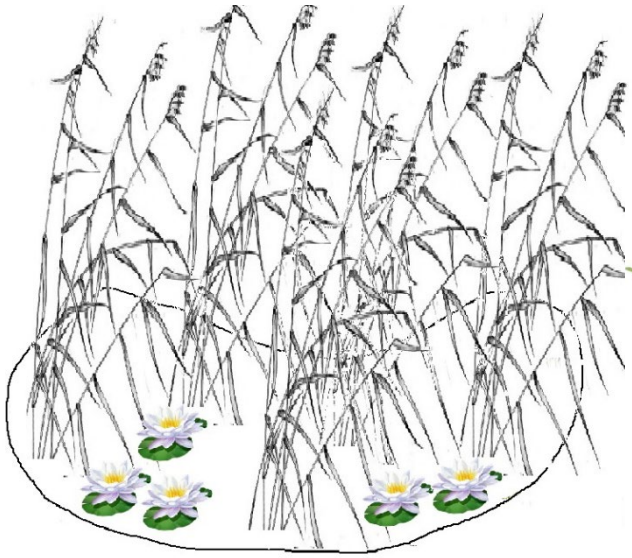


CLASS: Cattail and Others

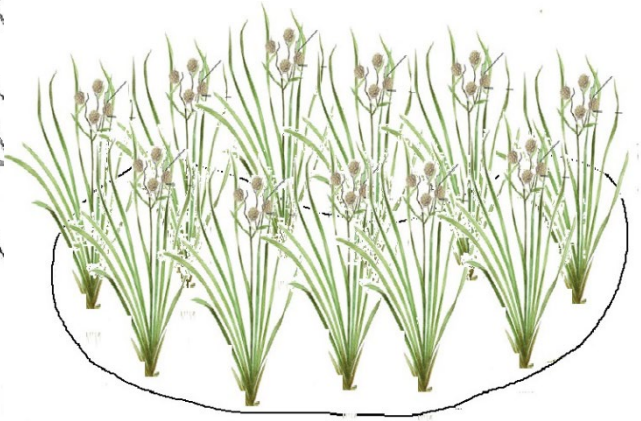


CLASS: Other Emergents

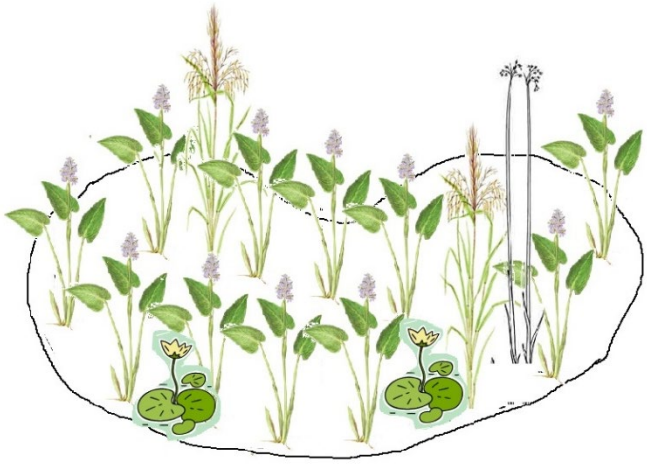
Common reed grass – white waterlily



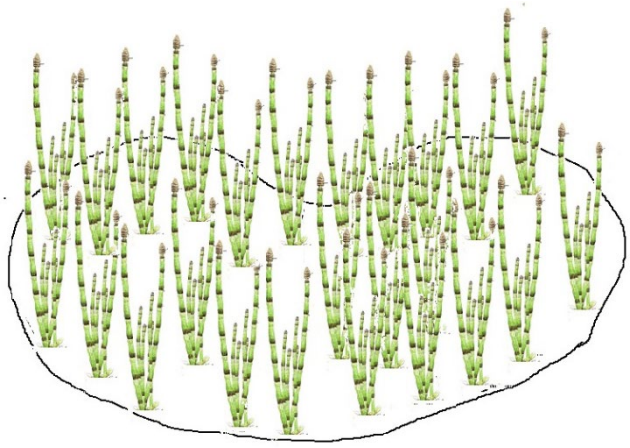
Bur reed



Pickerelweed

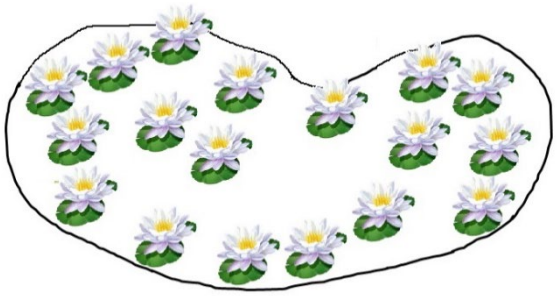


Horsetail

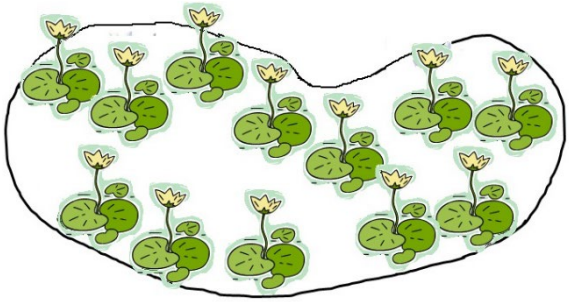


CLASS: Waterlilies

White waterlily



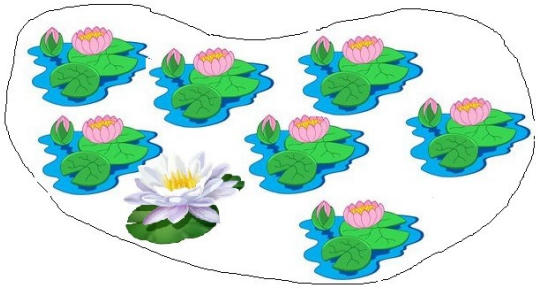
Yellow waterlily



White waterlily – Yellow waterlily

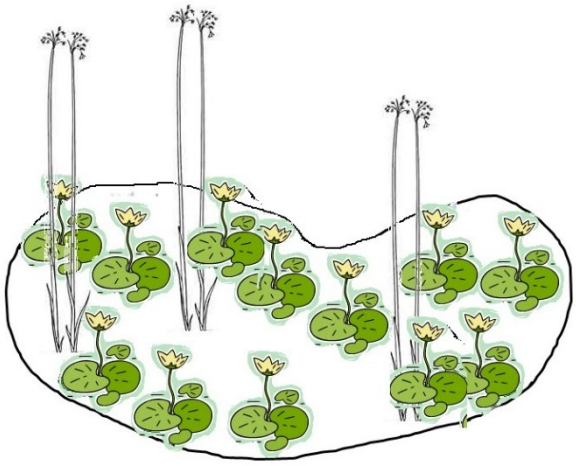


Hybrid Pink Waterlily

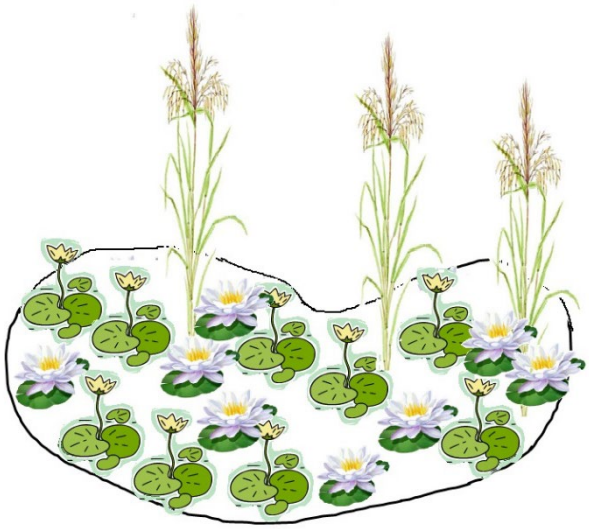


CLASS: Waterlilies with Emergents or other Floating-leaf plants

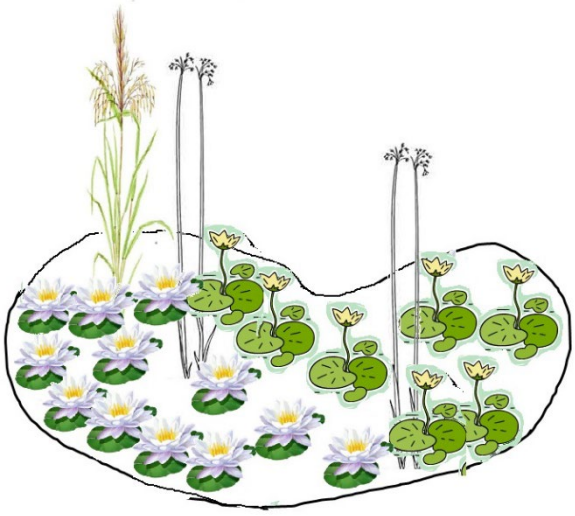
Waterlily– Bulrush



Waterlily – Wild Rice

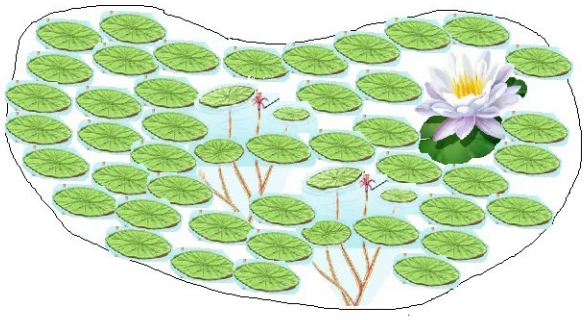


Waterlily - Bulrush

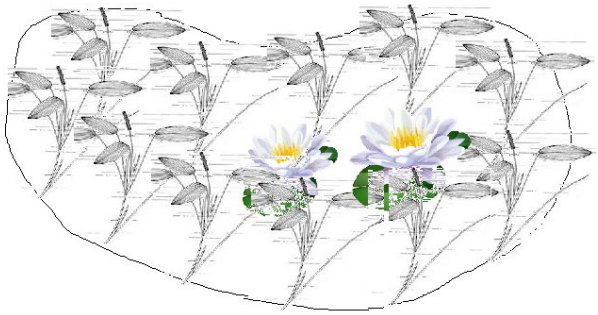


CLASS: Other Floating-leaf plants

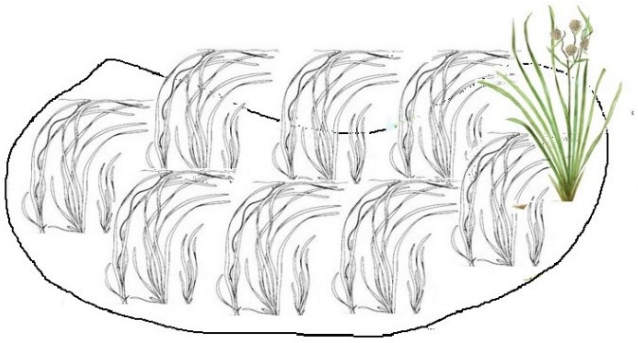
Watershield



Floating-leaf pondweed



Floating-leaf Bur reed



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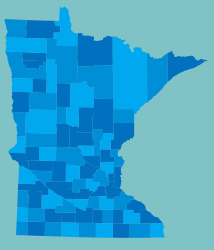
Coldwater lake habitats

November 2026

Development of water quality standards to protect coldwater lake habitats in Minnesota



MINNESOTA
Pollution Control Agency
Department of Natural Resources



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Document number: wq-bsm4-04

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Acronyms or abbreviations

2A	Coldwater aquatic life and habitat
2B	Cool and warm water aquatic life and habitat
2Bd	Cool and warm water aquatic life and habitat, also protected for drinking water
a_{440}	Absorptivity at 440 nm
BWCAW	Boundary Water Canoe Area Wilderness
CFR	Code of Federal Regulations
ch.	Chapter
Chl-*a*	Chlorophyll-*a*
CPUE	Catch-per-unit-effort
CWA	Clean Water Act (33 U.S.C. § 1251 et seq.)
DOC	Dissolved organic carbon
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FIBI	Fish index of biological (biotic) integrity
GAM	Generalized additive model
HUC 8	8-digit hydrological unit code (watershed subbasin)
IBI	Index of biological (biotic) integrity
mg/L	Milligrams per liter
Minn. R.	Minnesota Rules
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
ORVW	Outstanding resource value waters
PCU	Platinum-cobalt units
SSS	Site-specific standard
TALU	Tiered aquatic life use(s)
T_{DO}	Oxythermal habitat
T_{DO3}	Oxythermal habitat: temperature where dissolved oxygen concentration equals 3 mg/L
TMDL	Total maximum daily load
TP	Total phosphorus
TSD	Technical support document
UAA	Use attainability analysis
U.S.C.	United States Code
WID	Waterbody identification number
WQBEL	Water quality-based effluent limit
WQS	Water quality standards
WRAPS	Watershed restoration and protection strategies

Definitions

The following definitions are based on standard use and are provided for the convenience of the reader. Unless otherwise specified, these definitions are specific to this document.

Aquatic life use: A designated use that protects aquatic biota including fish, insects, mollusks, crustaceans, plants, microscopic organisms, and all other aquatic-dependent organisms.

Aquatic life use goal: A goal for the condition of aquatic biota, which is required by the Clean Water Act (CWA). Minimum aquatic life use goals are established using the CWA interim goal ("…water quality which provides for the protection and propagation of fish, shellfish, and wildlife…" CWA Section 101(a)(2) [33 U.S.C. § 1251]). The objectives for these goals are established in Minnesota Rule using narrative standards, numeric standards, or both. The condition or health of aquatic life in aquatic habitats are measured in Minnesota using indices of biological integrity (IBIs) and other tools.

Beneficial use: A designated use described under Minn. R. 7050.0140 and listed under Minn. R. 7050.0400 to Minn. R. 7050.0470 for each surface water or segment thereof, whether or not the use is being attained. (The term "designated use" may be used interchangeably.) See also "existing use."

Biological integrity: The ability of an aquatic ecosystem to support and maintain an assemblage of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.

Biological monitoring: The measurement of a biological entity (taxon, species, assemblage) as an indicator of environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods. (The term "biomonitoring" may be used interchangeably.)

Clean Water Act (CWA): An act passed by the United States Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). 33 U.S.C. § 1251 et seq.

Criteria: Narrative descriptions or numerical values, which describe the chemical, physical, or biological conditions in a water body necessary to protect designated uses

Designated use: See "beneficial use."

Dimictic lake: Lakes which mix twice a year in the spring and fall and are stratified during the summer and winter. Compared to polymictic lakes, dimictic lakes tend to be deeper with the littoral zone comprising a lower proportion of the total area.

Existing use: Those uses actually attained in a surface water on or after November 28, 1975. See Minn. R. 7050.0255, subp. 4.

Index of biological integrity or index of biotic integrity (IBI): An index developed by measuring attributes of an aquatic community representing the health of that community and that change in quantifiable and predictable ways in response to human disturbance.

Oxythermal habitat: A measure of temperature and dissolved oxygen in a water column where both dissolved oxygen and temperature is suitable to support coldwater fish communities during critical periods. For assessments, an oxythermal metric called T_{DO3} which is the temperature at 3 mg/L of dissolved oxygen in a lake profile is used.

Oxythermal layer: A water column layer of a designated thickness where both dissolved oxygen and thermal conditions need to be maintained at levels that support coldwater fish communities during

critical periods. Oxythermal layer criteria may be defined using different methods including a fixed layer thickness which meet defined temperature and oxygen criteria or by determining the water temperature at which a dissolved oxygen threshold is meet in a lake profile. The layer thickness method could for example require a 1 m layer where the water temperature is less than 20 °C and dissolved oxygen is greater than 3 mg/L. The temperature threshold method can for example be used to require that water temperature be less than 20 °C on the lake profile where the dissolved oxygen equals 3 mg/L. The later method (i.e., temperature threshold) is used for setting draft oxythermal habitat criteria for cold water fishes in Minnesota.

Polymictic lake: Lakes with frequent mixing of the water column during the ice-free period. In general, these lakes are shallow and are largely consistent with the shallow lake definition in Minn. R. 7050.0150, subp. 4.

Standard: Regulatory limits on a particular pollutant, or a description of the condition of a water body, which supports or protects the beneficial use or uses. Standards may be narrative or numeric and are commonly expressed as a chemical concentration, a physical parameter, or a biological assemblage endpoint. See also the definition for "criteria."

Use attainability analysis (UAA): A structured scientific assessment of the physical, chemical, biological, and economic factors affecting attainment of the uses of water bodies. A UAA is required to remove a designated use specified in section 101(a)(2) of the CWA that is not an existing use. The allowable reasons for removing a designated use are described in 40 CFR § 131.10 (g). See Minn. R. 7050.0150, subp. 4.

Water quality standards (WQS): A law or regulation that consists of the beneficial use or uses of a water body, the narrative or numerical WQS that are necessary to protect the use or uses of that water body, and antidegradation.

Overview

The State of Minnesota has adopted water quality standards (WQS) that protect coldwater lake habitats, but it is necessary for water quality programs to review and revise existing standards as needed when new information is available or gaps in these standards are identified. One of the gaps identified for Minnesota's current coldwater lake standards is that they are focused only on lakes which support or are managed for trout species (e.g., Lake Trout [*Salvelinus namaycush* (Walbaum, 1792)], Brook Trout [*Salvelinus fontinalis* (Mitchill, 1814)], Rainbow Trout [*Oncorhynchus mykiss* (Walbaum, 1792)], Brown Trout [*Salmo trutta* Linnaeus, 1758]; Table 1). Minnesota's standards do not include protections for other coldwater fishes which occur in the state including Lake Whitefish (*Coregonus clupeaformis* [Mitchill, 1818]) and Cisco (*Coregonus artedi* Lesueur, 1818). The objectives of this study were to 1) determine if current lake standards are sufficient to protect coldwater fishes, 2) evaluate whether there are gaps in protections, and if so what WQS revisions are needed, and 3) identify specific lakes which support coldwater fish species.

Table 1. Minnesota's current lake eutrophication standards for coldwater (Class 2A) and warm water (Class 2B/2Bd) habitats.

Species	Total phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi depth (m)
Coldwater: Lake Trout	12	3	4.8
Coldwater: Stream Trout	20	6	2.5
Warm water: Northern lakes*	30	9	2.0
Warm water: Central lakes	40	14	1.4
Warm water: Central shallow lakes	60	20	1.0
Warm water: South lakes	65	22	0.9
Warm water: South shallow lakes	90	30	0.7

**The lake eutrophication standards for northern cool water and warm water lakes are currently being reviewed and will likely be revised concurrently with coldwater lake standards. The draft standards for northern warm water, dimictic lakes are total phosphorus = 20 µg/L; chlorophyll-a = 9 µg/L; Secchi depth = 1.8 m. Draft standards for northern warm water, polymictic (i.e., shallow) lakes are total phosphorus = 32 µg/L; chlorophyll-a = 18 µg/L; Secchi depth = 0.9 m. The lake eutrophication standards for Central and South region lakes would not be revised as part of this rule making.*

Coldwater lakes are an important resource in Minnesota because they provide a variety of beneficial uses. Many of these lakes harbor one or more species of Salmonidae including Lake Trout, Lake Whitefish, Cisco, or stream trout species/hybrids (e.g., Brook Trout, Rainbow Trout, Brown Trout, and splake). A major difference in the ecological requirements of coldwater species compared to cool and warm water species is the need for habitat with cooler temperatures and higher oxygen levels. However, as in most taxonomic assemblages, the species comprising Salmonidae in Minnesota have different ecological requirements and need different WQS for their protection. As a result, this research focused on developing different dissolved oxygen, temperature, and lake productivity (i.e., chlorophyll-*a* [chl-*a*]) thresholds for Lake Trout, Lake Whitefish, and Cisco. Thresholds for protecting stream trout taxa were not assessed because these taxa are heavily managed through stocking and include a range of fishery types, including "put-and-take" fisheries, which complicates the use of field-based analyses. As a

result, the chl-*a* standard for the protection of stream trout habitat will not be changed from current standards[1].

Analyses of coldwater fish distributions in Minnesota lakes were used to determine oxythermal (i.e., dissolved oxygen and temperature) requirements and lake productivity levels needed to support these fish species. This consisted of an analysis of oxythermal requirements for Cisco, Lake Whitefish, and Lake Trout using a measure of the water temperature at which dissolved oxygen equaled 3 mg/L in the water column (i.e., T_{DO3}). Analyses of lake productivity thresholds for these fish species followed Minnesota's existing lake eutrophication framework and determined requirements for chl-*a*, total phosphorus, and Secchi depth. These analyses verified that in many lakes, the cool/warm water habitat (Class 2B/2Bd) standards are not sufficient to protect these coldwater fish species. The one exception was the eutrophication parameters for Cisco in the northern nutrient region where the existing standards for dimictic lakes would be protective. However, there is currently no oxythermal habitat measure for lakes in rule so the addition of this parameter would add additional protections to these lakes. A suite of draft WQS criteria, including both oxythermal and eutrophication measures were developed to protect these sensitive fish species (Table 2). The draft oxythermal standards are new and unique to coldwater lakes and will provide a direct measure of habitat suitability for coldwater fishes. For Lake Trout, we confirmed the existing chl-*a* standard is protective although revisions to total phosphorus (TP) and Secchi depth models indicated that these parameters should be revised. The draft eutrophication standards for Lake Whitefish are more protective than the existing standards for these lakes. For Cisco the protectiveness of existing eutrophication standards is mixed. For central region lakes, the existing eutrophication standards are not sufficiently protective. However, the northern region lake standards are more protective than determined for Cisco and as a result, the more protective warm water standards would apply to these lakes (Table 2). This is because these lakes are two-story lakes which support both warm water and coldwater communities and it is necessary to apply the more stringent standards to protect the most sensitive community. These WQS will be adopted in Minnesota rules as part of the lake eutrophication standards for Class 2A waters (Minn. R. 7050.0222, subp. 2).

Table 2. Draft oxythermal habitat (T_{DO3}), total phosphorus, chlorophyll-*a*, and Secchi depth thresholds for Lake Trout (LAT), Lake Whitefish (LKW), Cisco (TLC), and stream trout (SRT) coldwater (Class 2A) habitats.

Species	T_{DO3} (°C)	Total phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi depth (m)
Coldwater: Lake Trout [LAT]	8.8	7	3*	3.5
Coldwater: Lake Whitefish [LKW]	17.2	12	5	2.8
Coldwater: Cisco [TLC][#]	21.2	25	12	1.3
Coldwater: Stream trout [SRT]	-	15	6*	2.5

** indicates a threshold which is unchanged from the current standard*

[#]The draft North region cool and warm water lake eutrophication criteria for dimictic lakes (total phosphorus = 20 µg/L; chlorophyll-a = 9 µg/L; Secchi depth = 1.8 m]) are more stringent than the Cisco eutrophication standards and will be the applicable standard for Cisco lakes in the North region. In Central region Cisco lakes, the Cisco eutrophication standards are more stringent and will be the applicable standard.

In addition to determining protective thresholds for coldwater fish species, we developed a list of lakes[2] which support or supported coldwater fish populations on or after November 28, 1975. These lakes are part of a list of lakes that will be proposed to be confirmed or newly designated as Class 2A for the

[1] The current standards are largely based on the 75th percentiles of water quality parameters from lakes managed for stream trout (Heiskary and Wilson 2005).

[2] For Lake Trout, Lake Whitefish, and Cisco, the draft list of designated lakes is limited to dimictic lakes. Stream trout lake designations include both dimictic and polymictic lakes.

protection of coldwater habitat. The current aquatic life use designations for Class 2A lakes are based on the presence or management of either Lake Trout or stream trout. Revisions to the list of coldwater habitats will include confirming use designations for Lake Trout or stream trout and will add Cisco and Lake Whitefish protections to lakes where appropriate. Although the current coldwater lake standards are based on protections for Lake Trout or stream trout, these species-specific designations are not codified in Minn. R. 7050.0470. As a result, Minn. R. 7050.0470 will be revised to document and codify the coldwater fish species protected in each lake. The review of coldwater habitats in this document includes confirmations or changes to use designations for a total of 731 lakes (see Appendix C). This includes 411 new coldwater habitat designations, 295 lakes where the current designated use class was confirmed, and 25 lakes where Class 2Bd was determined to be appropriate (Table 3). For the 295 lakes where the current designated use will be retained, 88 of these lakes have modifications to the fish species protected. The total draft designations included 111 Lake Trout lakes, 87 Lake Whitefish lakes, 465 Cisco lakes, and 170 stream trout lakes (Table 4).

Table 3. Summary of draft beneficial use designations for coldwater lakes. Abbreviations: LAT = Lake Trout (*Salvelinus namaycush*); LKW = Lake Whitefish (*Coregonus clupeaformis*); TLC = Cisco (*Coregonus artedi*); SRT = stream trout.

Current use[3]	Draft use	# of lakes	Type
2B/2Bd	2A[LAT/LKW/TLC/SRT]	411	2A designation
$2A^{LAT/SRT}$	2A[LAT/SRT]	207	Species confirmation
$2A^{LAT/SRT}$	2A[LAT/LKW/TLC/SRT]	88	Species modification
$2A^{LAT/SRT}$	2Bd	25	2Bd designation

Table 4. Number of lakes protected for each coldwater fish species based on draft designations.

Coldwater species	# of lakes
Lake Trout	111
Lake Whitefish	87
Cisco	465
Stream trout	170

The draft WQS for coldwater habitats and designations for specific lakes will provide appropriate protections for these sensitive fishes. The assignment of different criteria for different fish species provides refined goals that are tailored to the requirements of these species. These draft WQS consist of multiple endpoints (i.e., oxythermal habitat and eutrophication) which provide several advantages including:

1) Oxythermal habitat criteria directly measure if habitat is suitable for the survival of coldwater species;
2) Eutrophication criteria are consistent with existing WQS and provide targets for water quality management (e.g., total maximum daily load [TMDLs] studies, water quality-based effluent limits [WQBELs], watershed restoration and protection strategies [WRAPS]);
3) Multiple endpoints can be used to partition different threats including cultural eutrophication and climate change;
4) Multiple endpoints provide different options for assessing attainment of goals; and
5) Multiple endpoints can be used to determine if lakes are atypical when endpoint outcomes do not align.

[3] The type of coldwater habitat (i.e., the species of fish protected by the Class 2A designation) is currently not codified in Minn. R. 7050.0470. The current coldwater habitat type has been determined through a review of existing documentation. As part of this rule revision, fish species protected in each lake will be codified for clarity.

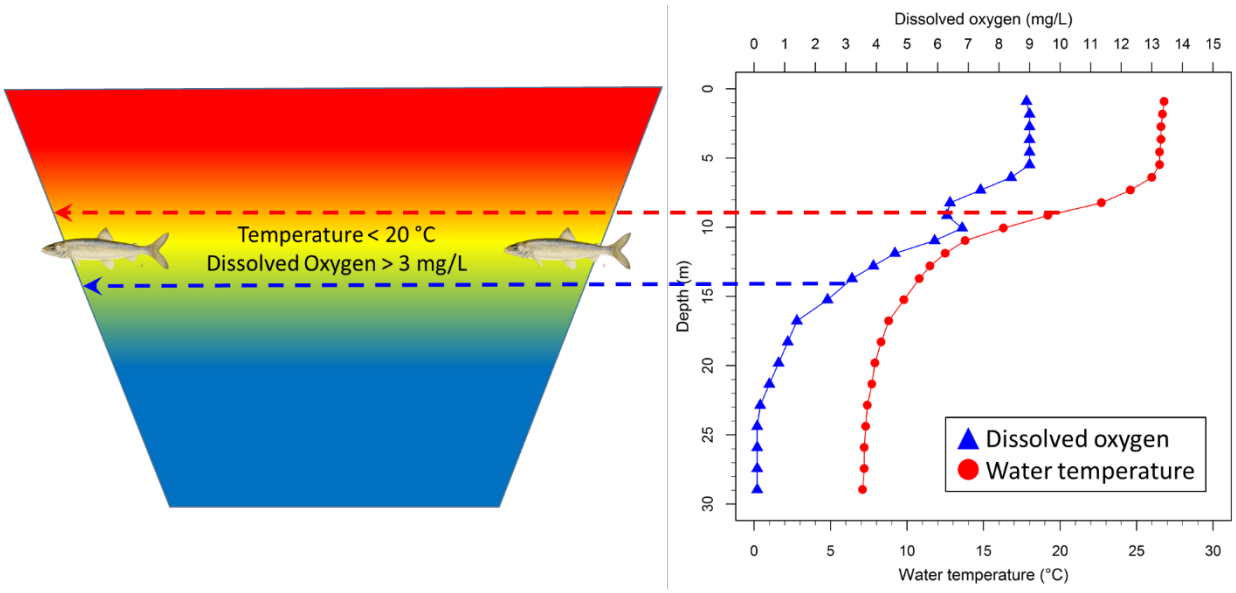
These improved tools for protecting coldwater lakes are coupled with an extensive review of coldwater lakes in Minnesota to determine which species should be protected in this subset of lakes. This provides clarity regarding the specific goals that are needed to support these fish species and the fisheries upon which they rely. Using these well-delineated goals, the MPCA, MNDNR, other agencies, organizations, or groups responsible for the protection of Minnesota's aquatic resources can implement protection and restoration programs to maximize effectiveness and efficiency. Given the threats that coldwater fishes and their habitats face, the responsible and effective use of available resources will be vital to ensuring that these habitats and the benefits they provide persist.

Introduction

Coldwater fish species provide several important benefits and uses to Minnesota lakes. Lake Trout are a very popular and important game fish in Minnesota's northern lakes and Lake Superior. Minnesota has more lakes supporting Lake Trout than any other state other than Alaska, making these lakes an important and unique resource in the United States. Other native salmonids such as Cisco and Lake Whitefish are not as popular as many other gamefish in the state, but they are netted and are also targeted by some anglers. Coldwater fishes such as Cisco and Lake Whitefish are also important forage for other game fishes (e.g., Lake Trout, Northern Pike (*Esox lucius* Linnaeus, 1758), Muskellunge (*Esox masquinongy* Mitchill, 1824), and Walleye (*Sander vitreus* (Mitchill, 1818)). For example, when fish like Cisco are present in a lake, the presence of this forage base can increase size of game fish and fishery yields (Trippel and Beamish 1989, Matuszek et al. 1990, Siesennop 1998, Kaufman et al. 2009, Kennedy et al. 2018, Vanderbloemen et al. 2020). These species are also very sensitive to environmental change and are useful indicators of water quality changes and declines. Their sensitivity to changes in temperature and lake productivity means that many populations of these coldwater fishes are at risk from nutrient enrichment and climate change. Recognizing the importance of these species, the MNDNR has developed several programs which provide protections for lakes supporting these fish species including Cisco Refuge Lakes, Lakes of Biological Significance, and Lakes of Phosphorus Sensitivity. Wisconsin has also adopted WQS rule revisions to specifically address protection of coldwater fishes. In addition, the EPA has developed recommended eutrophication standards (EPA 2021) which include standards for deepwater hypoxia and would benefit coldwater fish species.

Coldwater fishes differ in their habitat requirements compared to cool and warm water species in requiring cooler water with higher oxygen levels. Coldwater species are largely limited to deep, low nutrient lakes in Minnesota. During the summer when these lakes stratify, cooler, well-oxygenated water is present below the thermocline which provides a summer refuge for these species (Figure 1). If annual summer water temperatures increase, the available habitat for these species shrinks and they are forced deeper into the lake (Sharma et al. 2011). However, deepwater oxygen depletion can also force fish higher in the water column which narrows the available habitat for coldwater fishes (Siesennop 2000, Aku et al. 1997, Havens et al. 2014, Lyons et al. 2018). Cultural eutrophication reduces deepwater oxygen levels by increasing productivity, deposition of organic matter, and subsequently oxygen demand in the sediment and hypolimnion (Sharma et al. 2011, Havens et al. 2014). Rising temperatures can also reduce oxygen levels by increasing respiration and extending the period between spring and fall lake turnover (De Stasio et al. 1996, Stefan et al. 1998, Stefan et al. 2001, Sharma et al. 2011). Depending on the lake, coldwater fishes may be threatened by either temperature or productivity increases or both as suitable habitat shrinks. As a result, it is important to address both threats as part of a WQS framework for the protection of coldwater fish species.

Figure 1. Conceptual diagram of oxythermal requirements for coldwater fishes. Oxythermal criteria provided here are based on the "Cisco layer" described by Frey (1955).



The two largest threats to coldwater fish populations in the Upper Midwest are eutrophication and climate change (Jacobsen et al. 2019). Climate change will increase lake temperatures, extend the period of stratification (i.e., longer summers), and reduce dissolved oxygen levels in lakes (Woolway et al. 2019, Jane et al. 2021). Depending on different warming scenarios, increased temperatures are estimated to result in the loss of 25-70% of Cisco lakes in Minnesota and Wisconsin (Sharma et al. 2011, Fang et al 2012, Jiang et al. 2012, 2017, Custer et al. 2024). These fish also face threats from nutrient loading (Herb et al. 2014, Honsey et al. 2016) which increases oxygen depletion in deepwater habitats. Invasive species such as Rainbow Smelt (*Osmerus mordax* (Mitchill, 1814)) also threaten these species and have likely resulted in several coldwater fish species extirpations in Minnesota. The combination of these threats has resulted in a decline in the catch-per–unit-effort (CPUE) of these species since the 1960s as measured by MNDNR fisheries surveys (Jacobson et al 2012). Due to the declines in these species and their sensitivity to habitat degradation, it is important to have well-designed and effective WQS coupled with water quality protection programs.

Coldwater fishes are an important component of many Minnesota's lakes, but current WQS may not adequately protect some coldwater fish species. Currently, cool/warm water standards apply to some lakes which support salmonids such as Cisco and Lake Whitefish. As a result, productivity and hypolimnetic dissolved oxygen conditions which meet cool/warm water standards in these lakes could still result in the extirpations of these species. In addition, the current dissolved oxygen and temperature standards for cold and cool/warm lakes are not specific to the protection of coldwater fishes. Dissolved oxygen standards are 7 mg/L for coldwater lakes and 5 mg/L for cool/warm water lakes, but these standards do not specify oxygen levels for the hypolimnion or metalimnion which are critical habitats for coldwater fishes in the summer in dimictic lakes. A lake may have normoxic conditions in the epilimnion and meet dissolved oxygen standards while the hypolimnion or metalimnion is hypoxic or anoxic. Temperature standards for coldwater lakes do not allow any "material increase" which in theory should be sufficient to protect coldwater taxa. However, in practice this is more difficult to implement, and it is not specific to different coldwater fish taxa. As a result, review of oxygen and temperature requirements and development of specific, protective thresholds for coldwater fishes is warranted in conjunction with a review of existing eutrophication criteria.

Minnesota's coldwater fishes

Minnesota lakes support several native cold and cool water fish species including Lake Trout, Lake Whitefish, several species of Cisco, and Burbot. In addition, several native and non-native coldwater fish species and hybrids (e.g., Brook Trout, Rainbow Trout, Brown Trout, and splake) are stocked into lakes to create managed fisheries. This study is focused on assessing if new or revised standards are needed to protect Lake Trout, Lake Whitefish, and Cisco. This effort does not include analyses of Burbot (*Lota lota* (Linnaeus, 1758)) because gear types used in most fisheries surveys inadequately sample this species making the available data inadequate for assessment. The existing WQS for stream trout lakes was not extensively reviewed as part of this research and there are only minimal changes to the WQS that protect these fish species. The heavily managed nature of stream trout fisheries in lakes made it difficult to assess habitat requirements using field-based data analyses and therefore the existing criteria are largely retained.

Native populations of coldwater fish species are largely limited to north central and north eastern watersheds in Minnesota although some introductions have been successful outside of their native range. Native populations of Lake Trout are limited to the Rainy River and Lake Superior watersheds (Hatch 2015). Hatch (2015) lists Cisco and Lake Whitefish as being native to the Red River, Rainy River, Lake Superior, and Mississippi River Headwaters (upstream of the confluence with the St. Croix River) basins. Although Hatch (2015)[4] lists Cisco as being introduced into the St. Croix River basin, there is evidence that Cisco are native to this watershed above St. Croix Falls. For example, Grindstone and Hanging Horn lakes support or are thought to have once supported[5] native populations of Cisco. Cisco are also present in the St. Croix watershed below St. Croix Falls in Lake Elmo, but there are stocking records indicating that the presence is the result of stocking. In addition, Cisco may also be native in a small number of lakes in the Chippewa and Pomme de Terre watersheds in the Minnesota River basin. Miller et al. (2021) also determined that Cisco in Rachel Lake (Chippewa River watershed) and Cisco from several nearby lakes in the Mississippi River basin were composed of a single ancestral group. There is no evidence of stocking for the Minnesota River basin lakes, and they are close to watershed boundaries with the Mississippi River and Red River watersheds which suggests these populations are possibly native.

The following sections describe existing knowledge of coldwater fishes in Minnesota with a focus on oxythermal requirements for these species. Depending on the study, different temperature, and oxygen endpoints (e.g., optimum, lethal, preference) are used which makes comparison across studies difficult. These studies also use a variety of methods, fish year classes, and research settings (e.g., field and laboratory). It is not within the scope of Minnesota's standards development to extensively review these methods and determine environmental optima for these coldwater fishes from this literature. Rather this research provides a summary of previous research to help guide threshold development and to put draft values into the context of reported thermal and oxygen optima and lethal conditions. The draft WQS is based on extensive datasets from Minnesota lakes to ensure that these criteria are applicable to these habitats.

[4] Hatch (2015) limited watershed presence to records where the specimen could be examined.
[5] The cisco population in Grindstone is thought to have been extirpated due to the introduction of Rainbow Smelt in this lake based the absence of cisco in MNDNR fisheries surveys since the 1990s.

i. Cisco

Cisco (Lake Herring or Tullibee) is one of the most common and widespread salmonids in Minnesota (Eddy and Surber 1943), occurring in lakes throughout northern Minnesota and even in some lakes in the Minnesota, Red, and St. Croix river basins. Although less so than many other salmonid species, Cisco require cool, well-oxygenated water and are largely limited to deep, cool lakes which stratify in the summer. However, there are also some polymictic lakes, largely in northern Minnesota, which also apparently support self-sustaining populations. Their importance for fisheries is largely not related to their use as a game fish, although Cisco are a good food fish and there is some fishing pressure on these populations. For example, there is an important Cisco fishery on Lake Superior. Their greatest benefit may be a as food source for other popular fish species such as Walleye, Northern Pike, Muskellunge, and Lake Trout.

There are several cisco species in Minnesota although the exact number varies depending on the taxonomists or taxonomic resource. The taxonomy of cisco species is confusing due to the morphological plasticity of these species and the difficulty of delineating distinct morphological and genotypic types (Koelz 1931, Woodger 1976, Turgeon et al. 2016). For example, Jacobson et al. (2020) determined that the morphology of Cisco changed along a gradient of lake productivity. Hatch (2015) lists five cisco species (*C. artedi, C. hoyi, C. kiyi, C. nipigon*, and *C. zenithicus*) and indicates that other than *C. artedi*, these species are limited to Lake Superior. However, Etnier et al. (2003) identified *C. nipigon* and *C. zenithicus* from Lake Saganaga and there may be other inland lakes in Minnesota that support additional cisco species. However, it is not known if these other cisco species have different water quality requirements than *C. artedi* due to the small number of lakes supporting these species and a lack of consensus regarding the delineation of these species. Regardless, lakes that potentially support other cisco species also support Lake Trout or Lake Whitefish and would thereby be protected by these more stringent standards. As a result, the current research is focused on *C. artedi* because this species is widespread in central and northern Minnesota and there is sufficient data to determine ecological thresholds for this species. Although it is beyond the scope of this research, determining the ecological requirements of the other cisco species in Minnesota is important for their protection. However, developing standards for these species is not currently a priority because Lake Superior and the portion of Lake Saganaga in the U.S. already have some the most stringent WQS in Minnesota as both are classified as prohibited outstanding resource value waters[6]. Hereafter, the focus of this research is on *C. artedi* and unless otherwise noted, references to "Cisco" refer to this species alone.

There are numerous laboratory and field-based assessments of the dissolved oxygen and temperature requirements of Cisco (Table 5). Regardless of the endpoint, studies of dissolved oxygen requirements for Cisco were largely consistent and indicated that dissolved oxygen concentrations ranging from 1-3 mg/L were sufficient for survival. In a study of lakes experiencing summertime Cisco kills, Jacobson et al. (2008) determined that 0.5 mg/L is a lower lethal concentration for Cisco. However, the authors note that the lower lethal concentration is likely higher. Temperature thresholds for Cisco were more variable with upper limits ranging from 17-26 °C. Preferred or optimal temperatures ranged from 10-19 °C with most studies indicating 17-19 °C to be optimal. However, it is important to consider the interaction of oxygen and temperature on these fish which when considered separately will introduce variably in ecological threshold determinations.

[6] Prohibited outstanding resource value waters prohibit proposed activities that result in a "net increase in loading or other causes of degradation" (Minn R. 7050. 0265).

Frey (1955) proposed that a ‘‘cisco layer’’ with dissolved oxygen of 3 mg/L and water temperature of 20°C for the protection of Cisco in Indiana lakes. Wisconsin has adopted[7] a standard for Cisco which requires a 1 m layer of habitat with dissolved oxygen of >6 mg/L and water temperature of <22.8 °C. In Minnesota, Jacobson et al. (2008) demonstrated that the lower lethal dissolved oxygen for Cisco is temperature dependent, and that protection of these fish needs to consider both parameters (Table 6). Using a fixed dissolved oxygen threshold permits the identification of a consistent temperature endpoint. For example, Jacobson et al. (2010) used a dissolved oxygen of 3 mg/L to identify oxythermal niches for Cisco in Minnesota lakes. Jacobson et al. (2010) determined that the upper central and upper outer borders (see Heegaard 2002) for Cisco were 16.9 and 23.4 °C, respectively. The inner border represents the core habitat for the species whereas the outer border is the entire range for the species (Jacobson et al. 2010). This T_{DO3} measure has been used in several studies of coldwater lake fish habitat in Minnesota (e.g., Jacobsen et al. 2010, Fang et al. 2012, and Jiang et al. 2017). The use of this oxythermal metric in existing studies of Minnesota coldwater fishes and the incorporation of both temperature and oxygen measures makes the use of this metric preferable for determining coldwater habitat thresholds for Minnesota lakes.

Table 5. Summary of dissolved oxygen and temperature thresholds for Cisco (*Coregonus artedi*).

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Aku and Tonn (1997); Aku et al. (1997)	3.1 ± 1.3 (preferendum); 1.3 (avoidance concentration)	11.8 ± 2.1 (preferendum)	Amisk Lake, Alberta, Canada	Maximum abundance recorded
Cahn (1927)	-	17 (upper avoidance)	Wisconsin, USA	
Carlander (1969)	-	15.5 (upper avoidance); 13 (preferendum)	Lake Nippissing, Ontario, Canada	Cited in Wismer and Christie (1987)
Edsall and Colby (1970)	-	26.2 (upper lethal)	Laboratory	young-of-the-year Cisco
Edsall and DeSorcie (2002)	-	14.5 (optimum growth); 16.5 (preferendum); 26 (upper lethal)	Laboratory	Age 0 Cisco
Evans et al. (1996)	2.0 (greatest abundance)	-	Lake Simcoe, Ontario, Canada	Mean dissolved oxygen concentration at which fish were caught
Fry (1937)	-	20 (upper avoidance); 10 (preferendum)	Lake Nippissing, Ontario, Canada	Cited in Coutant (1977)
Frey (1955)	3 (minimum)	20 (maximum)	Indiana (USA) lakes	
Galligan (1951)	-	7.2 (preferendum)	Cayuga Lake, New York, USA	Cited in Coutant (1977)
Jobling (1981)	-	9.9-18.9 (preferendum)	Modeled	
Jacobson et al. (2008)	0.5 (lower lethal)	24 (upper lethal)	17 Minnesota (USA) lakes	Upper lethal temperature under normoxic conditions

[7] Administrative Rules Chapter NR 102 WATER QUALITY STANDARDS FOR WISCONSIN SURFACE WATERS

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Jacobson et al. (2010)	-	16.9 (central); 23.4 (outer)	Minnesota (USA) lakes	Based on temperature at 3 mg/L of dissolved oxygen
McCormick et al. (1971)	-	18.1 (optimum growth); 19.8 (lethal)	Laboratory	larvae
Nelson (1970)	1-3 (lower lethal)	18-26 (lethal)	Lake Itasca and Elk Lake, Minnesota, USA	Based on where fish were caught
Rudstam and Magnuson (1985)	1.9 (lower lethal)	12 (preferendum)	5 Wisconsin (USA) lakes	

Table 6. Modeled* results of the lethal niche boundary for adult Cisco from Jacobson et al. (2008).

O_{lethal} (mg/L)	1	2	3	4	5	6	7
T_{lethal} (°C)	19.5	21.2	22.0	22.6	23.0	23.3	23.6

*$O_{lethal} = 0.40 + 0.000006e^{0.59Tlethal}$

ii. Lake Whitefish

Lake Whitefish are similar to Cisco in terms of their importance and habitat requirements; however, the range of Lake Whitefish in Minnesota is more restricted. Lake Whitefish are found in far fewer lakes than Cisco and are limited to the Lake Superior, Rainy, Mississippi, and Red river basins. In addition, due in part to their larger size, Lake Whitefish are more important to anglers and commercial fisheries and there are inland lakes in Minnesota where netting of Lake Whitefish is allowed. Compared to Cisco, there are also fewer studies of oxygen and temperature thresholds for Lake Whitefish (Table 7). A single study from a lake in Ontario, Canada determined that the average dissolved oxygen at which fish were found was 2 mg/L which matched Cisco in that lake (Evans et al. 1996). Jacobson et al. (2010) used a dissolved oxygen of 3 mg/L to determine thermal requirements for Lake Whitefish in Minnesota lakes. Given the more restricted range of Lake Whitefish, it is likely they have more stringent oxythermal requirements than Cisco. Estimated optimal or preferred water temperatures for Lake Whitefish range from 12-17 °C and lethal temperatures have been determined to be as high as 26 °C although there are few studies which determined lethal temperature thresholds (Table 7). Using a dissolved oxygen of 3 mg/L, Jacobson et al. (2010) determined that upper central and upper outer borders (see Heegaard 2002) were 11.1 and 19.5 °C, respectively. The inner border represents the core habitat for the species whereas the outer border is the entire range for the species (Jacobson et al. 2010). This indicates that optimal temperatures may be near 11 °C and the upper range for the species is near 20 °C. Although there are limited data, these results suggest that temperatures less than 20 °C are needed to protect Lake Whitefish in Minnesota.

Table 7. Summary of dissolved oxygen and temperature thresholds for Lake Whitefish (Coregonus clupeaformis).

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Bernatchez and Dodson (1985)	-	12 (optimal swimming capacity)	Laboratory	Effect of temperature on swimming speed
Cooper and Fuller (1945)	-	11.9 (preferendum)	Moosehead Lake, Maine, USA	
Edsall (1999)	-	15.6-16.8 (preferendum)	Laboratory	Age-1 and age-0 fish

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Edsall and Rottiers (1976)	-	21-27 (upper lethal)	Laboratory	Based on different acclimation temperatures
Evans et al. (1996)	2.0 (greatest abundance)	-	Lake Simcoe, Ontario, Canada	Mean dissolved oxygen concentration at which fish were caught
Gorsky et al. (2012)	-	10-16 (greatest abundance)	Clear Lake, Maine, USA	Determined using acoustic telemetry
Hoagman (1974)	-	12-16 (preferendum)	Laboratory	Cited in Jobling (1981) and Coutant (1977)
Jacobson et al. (2010)	-	11.1 (inner); 19.5 (outer)	Minnesota (USA) lakes	Based on temperature at 3 mg/L of dissolved oxygen
Jobling (1981)	-	13.5-16.8 (optimum growth)	Modeled	
Madenjian et al. (2006)	-	11.1 (preference)	Lake Huron	Maximum temperature of tagged fish in early September
Magnuson et al. (1990)	-	12 ±2(preference)	Laboratory	
Opuszynski (1974)	-	10 (fingerlings); 17 (young fish)	Laboratory	Cited in Spotila (1979)
Qadri (1961)	-	7-14 (greatest abundance)	Lac la Ronge, Saskatchewan, Canada	Based on gill net sampling
Reckahn (1970)	-	17 (preferendum)	South Bay, Lake Huron, Ontario, Canada	Cited in Coutant (1977)
Tompkins and Fraser (1950)	-	12.7 (preferendum)	Laboratory	Cited in Christie and Regier (1988) and Ferguson (1958)

iii. Lake Trout

Lake Trout are one of the most sensitive fish species in Minnesota lakes and are only found in deep, low nutrient lakes. This species is only native to the Lake Superior and Rainy basins (possibly also the Mississippi River basin) and is only sustainable in a relatively small number of lakes in the state. Lake Trout are the largest native trout in North America, and they are an important fish for sport and commercial fisheries. Reported dissolved oxygen thresholds for Lake Trout range from 3-10 mg/L for optimal conditions with most estimated values at or near 6 mg/L (Table 8). Estimated lethal dissolved oxygen concentrations for Lake Trout range from 1-4 mg/L. Reported optimal water temperature thresholds for Lake Trout range from 4-13 °C with most studies indicating that 10 °C is optimal (Table 8). Lethal thresholds, including reports of maximum temperatures at which Lake Trout were observed, range from 16-24 °C. Lake Trout have lower thermal preferences than Lake Whitefish and Cisco and appear to also require higher dissolved oxygen levels. Jacobson et al. (2010) used a 3 mg/L threshold to determine oxythermal habitat requirements for Lake Trout which based on the upper central and upper outer borders (Heegaard 2002) were determined to be 5.1 and 6.8 °C, respectively. The inner border

represents the core habitat for the species whereas the outer border is the entire range for the species (Jacobson et al. 2010). Some studies indicated dissolved oxygen concentrations near 3 mg/L are lethal to Lake Trout (e.g., Gibson and Fry 1954, Paterson 1968, Evans et al. 1991, 1996).

Table 8. Summary of dissolved oxygen and temperature thresholds for Lake Trout (*Salvelinus namaycush*).

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Cooper and Fuller (1945)	8.3-10.1 (greatest abundance)	10-14 (greatest abundance)	Moosehead Lake, Maine, USA	Especially abundant at depths with these conditions
Dillon et al. (2003)	6 (optimal)	10 (optimal)	Lakes in Ontario, Canada	Based on other research
Edsall and Cleland (2000)	-	12.5 (highest growth); 10.1-10.2 (preferendum)	Laboratory	Age 0 fish
Evans et al. (1991)	Adults: 4.2 (lower threshold) 6 (response); 4 (incipient lethal) 2 (acute lethal)	Adults: 9.5 (±1.11); Juveniles: 10.2 (±1.12)	Adults – distribution; Juveniles - laboratory	Mean of published literature
Evans et al. (1996)	3.2 (greatest abundance)	-	Lake Simcoe, Ontario, Canada	Mean dissolved oxygen concentration at which fish were caught
Evans (2007)	6.6-7.5	-	Laboratory	¾ scope-for-activity at 4-14 °C
Galligan (1962); Webster et al. (1959)	-	7.2-12.8 (greatest abundance)	Cayuga Lake, New York, USA	Most fish captured at these temperatures; cited in Martin and Oliver (1980)
Gibson and Fry (1954)	3 (lethal)	23.5 (lethal); 15-17 (maximum activity)	Laboratory	Age 0 fish
Goddard et al. (1974)	-	11.5 (preferendum)	Laboratory	
Jacobson et al. (2010)	-	5.1 (inner); 6.8 (outer)	Minnesota (USA) lakes	Based on temperature at 3 mg/L of dissolved oxygen
Johnson (1975)	-	4-9 (greatest abundance); 15 (maximum)	Great Bear Lake, Northwest Territories, Canada	Based on gillnet surveys; cited in Martin and Oliver (1980)
Mac (1985)	-	9.2-12.6 (preferendum)	Laboratory	Preferendum determined at different rations
MacLean et al. (1990)	4 (usable) 6 (optimum)	15.5 (usable); 10 (optimum)	Lakes in Ontario, Canada	

Reference	Dissolved oxygen (mg/L)	Water temperature (°C)	Habitat	Notes
Magnuson et al. (1990)	-	10 ±2 (preference)	Laboratory	
Martin (1952)	-	6-18 (greatest abundance)	Redrock Lake, Ontario, Canada	Based on fisheries surveys
Martin and Oliver (1976)	>4 (minimum)	-	Lakes in Ontario, Canada	cited in Martin and Oliver (1980)
Martin and Oliver (1980)	-	6.1-7.2 (greatest abundance); 13.5 (upper limit)	Lake Tahoe, California/Nevada, USA	Based on fisheries surveys; unpublished data by Baker
Martin and Oliver (1980)	-	19.4 (upper limit)	Laboratory	All ages; unpublished data by Nolting
Martin and Oliver (1980)	>4 (greatest abundance)	-	Subalpine lakes in Colorado, USA	unpublished data by Nolting
McCauley and Tait (1970)	-	11.7 (preferendum)	Laboratory	
Novakowski (1955)	-	5-6 (greatest abundance); 17.5 (upper limit)	Reindeer Lake, Saskatchewan, Canada	Based on fisheries surveys; cited in Martin and Oliver (1980)
O'Connor et al. (1981)	-	10-12 (optimal growth)	Laboratory	Yearling trout
Paterson (1968)	1.4-2.9 (lethal)	-	Swan Lake, Alberta, Canada	Cited in Martin and Oliver (1980)
Peterson et al. (1979)	-	10.8 (preferendum)	laboratory	
Plumb and Blanchfield (2011)	>4-6 (greatest abundance)	<12-15 (greatest abundance)	Experimental Lake 373, Ontario, Canada	Used tagged fish
Rawson and Atton (1953); Rawson (1961)	3.6-4.3 (avoidance); 5.7 (no avoidance)	8-10 (greatest abundance); 16 (upper limit)	Lac la Ronge, Saskatchewan, Canada	Based on fisheries surveys
Séguin (1957)	-	17.8 (fry and fingerlings); 13.3 (yearlings)	Laboratory	
Sellers et al. (1998)	>6 (greatest abundance)	4-19 (greatest abundance)	3 small Canadian Shield lakes, Ontario, Canada	Temperature where fish were located differed between lakes
Snucins and Gunn (1995)	-	13-18 (location of tagged fish)	2 lakes, Ontario Canada	Body temperature of tagged fish
Straight (1969)	6 (greatest abundance)	<6 (greatest abundance); 18 (upper limit)	Alluring Lake, Ontario, Canada	Based on fisheries surveys; cited in Martin and Oliver (1980)

iv. Stream trout (multiple species and hybrids)

There are several stream trout (SRT) species and hybrids that are stocked in Minnesota lakes including: Brook Trout, Rainbow Trout, Brown Trout, and splake (Lake Trout ♀ x Brook Trout ♂). Like lake-dwelling salmonids, these fish species require cool, well-oxygenated water if they are to survive more than a season following stocking. However, there is limited information regarding their ecological requirements in lentic habitats. Most of these lakes are heavily managed because stream trout in Minnesota inland lakes are typically not naturally self-sustaining and are maintained through stocking. This management complicates field-based analyses of oxythermal and eutrophication requirements for these fish species. As a result, a threshold analysis for stream trout in lakes is not part of this study. Minnesota currently has lake eutrophication standards to protect stream trout lakes (TP: 20 µg/L; chl-*a*: 6 µg/L; Secchi depth: 2.5 m; Heiskary and Wilson [2005]). At this time, Minnesota is not considering major changes to these standards and the focus of this rule amendment for these lakes will be to review and confirm the list of stream trout lakes in rule.

Development of standards for the protection of coldwater fish in lakes

The analyses for determining oxythermal and eutrophication thresholds for Lake Trout, Lake Whitefish, and Cisco were based on field data to identify the ecological conditions under which these species occur in Minnesota. The oxythermal habitat analyses focused on separate T_{DO3} assessments for each fish species to determine the maximum T_{DO3} allowable, which will result in the maintenance of coldwater fish populations in most lakes. Eutrophication analyses were focused on identifying chl-*a* thresholds for these species and then modelling TP and Secchi depths which are consistent with protective levels of chl-*a*.

i. Data and methods

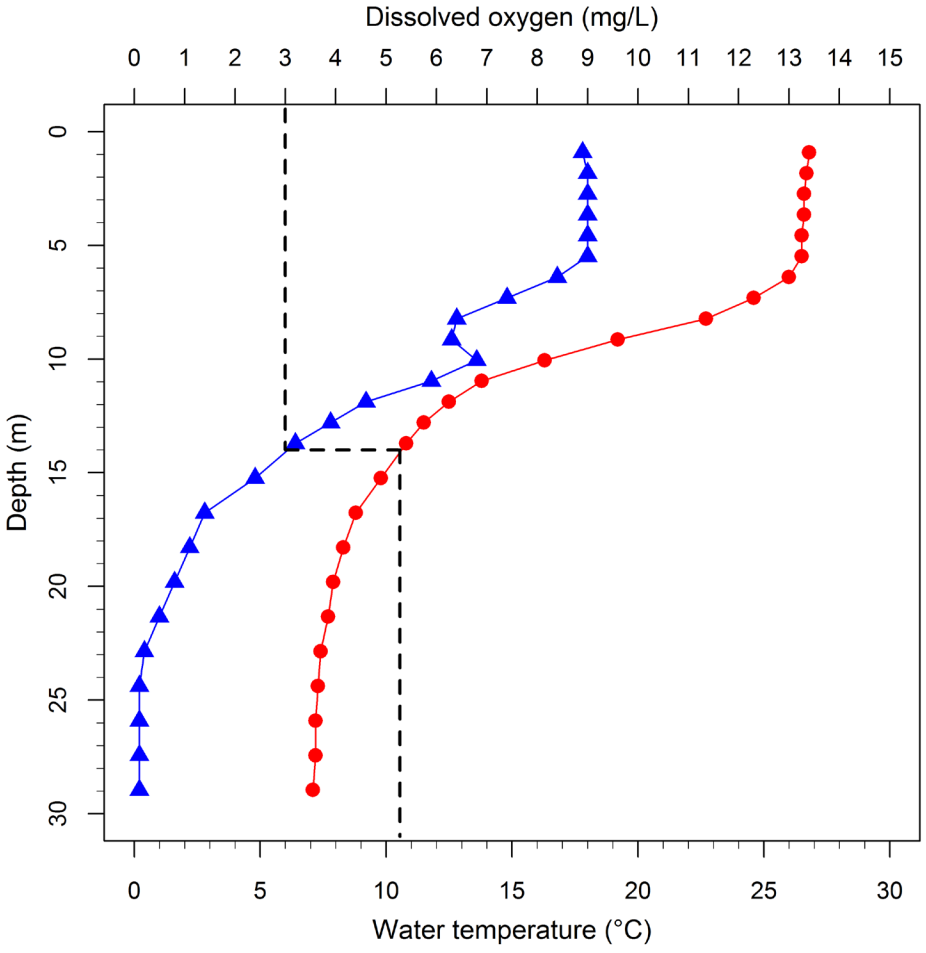
The specific datasets compiled and used were different for each analysis and are described in detail in the section for each analysis. Data used for most analyses consisted of data from 1990 through 2020. Data were limited to this range of years to estimate modern or contemporary oxythermal and productivity conditions for these lakes. In addition, this period has the greatest density of data available and sampling methodologies are more likely to be comparable.

a. Oxythermal habitat

Oxythermal habitat measures were calculated from temperature and oxygen profiles collected by the MNDNR and MPCA (1990-2020). Temperature and oxygen profiles were measured from lakes using electronic meters. Most profiles were measured using intervals ≤1 m (e.g., 1 ft, 3 ft, 1m). In some lakes, larger intervals were used in the hypolimnion when the rate of change in temperature and dissolved oxygen was observed to have greatly decreased. Oxythermal measures were calculated by interpolating a temperature using a fixed dissolved oxygen concentration from temperature and dissolved oxygen profiles. For example, a dissolved oxygen threshold of 3 mg/L was used to calculate T_{DO3} by interpolating water temperatures from dissolved oxygen and temperature profiles (Figure 2). In addition, using dissolved oxygen thresholds of 4, 5, 6, and 7 mg/L, T_{DO4}, T_{DO5}, T_{DO6}, and T_{DO7} metrics were calculated. Oxythermal layers of 1 m thickness based on Wisconsin's standards (Lyons et al. 2018) were also calculated. Some additional data processing was required to calculate T_{DOX} and oxythermal layer metrics for some profiles. For profiles where the minimum dissolved oxygen concentration (DO_{min}) was >3 mg/L,

the minimum temperature (T_{min}) was used to determine T_{DOx}. For lake profiles where maximum dissolved oxygen concentration (DO_{max}) was less than the oxygen target (e.g., 3 mg/L), the maximum temperature (T_{max}) was used in place of T_{DOx}. Temperature and oxygen profiles were typically measured from the deepest part of lakes to characterize the hypolimnetic conditions in these lakes; however, this was not always the case especially if multiple basins within a lake were sampled. If lake profiles were measured from multiple locations on the same lake on the same day, the minimum value was used as this was assumed to be the best habitat in the lake. Average T_{DOx} calculation used only lake profiles during the period of maximum oxythermal stress (July 26 through August 24). If multiple T_{DO3} measurements were available in the same year during this period, the maximum value was used as this represented the highest measured oxythermal stress for that year. When multiple years of data were available the average T_{DOx} was calculated. For most analyses, 3 years of oxythermal habitat data were required to calculate average values.

Figure 2. Example of T_{DO3} (temperature at a dissolved oxygen concentration of 3 mg/L) calculation from water temperature (red circles) and dissolved oxygen (blue triangles) profiles. Data: Rose Lake (56-0360-00), T_{DO3} = 10.6 °C, 3 August 2006).



b. Water quality data

Water quality datasets were queried and compiled from Minnesota's water quality Environmental Quality Information System (EQuIS) database (1990-2020). These parameters included TP, chl-*a*, Secchi depth, and dissolved organic carbon (DOC). Epilimnetic water samples were collected using either a 2-m long, 32-mm diameter integrated sampler or surface grab samples. Standard analytical methods were used for TP, chl-*a*, and DOC (Table 9). The reporting detection limit was variable, but the dataset was

screened for samples with a reporting detection limit greater than the reported value and these measurements were censored. All negative values were also removed. To address non-detects, one half of the reporting detection limit was used for analyses. Only data collected during the summer index period (June-September) were included. Most analyses in this study used only lakes with at least two years of water quality data and at least four measurements collected during the summer index period each year. Long-term summer averages for TP and chl-*a* were calculated as the average of individual summer averages.

Table 9. Summary of analytical methods used for water quality samples.

Water quality parameter	Analytical methods
Total phosphorus	365.1; 365.2; 365.3; 365.4; 4500-P (C, E, F, I)
Chlorophyll-*a*	10200-H; D3731-87; 445.0
Secchi depth	Field method
Dissolved organic carbon	5310-B; 5310-C; 9060A
Color	110.2; 110.3; 2120-B; 2120-C
Absorbance at 440 nm	see Brezonik et al. (2019)

c. Fisheries surveys

A large dataset of standard gill net fish surveys was available from the MNDNR and comprised most of the fish presence and abundance data used in these analyses. The fisheries datasets consisted of lake surveys performed from 1993 through 2020. The current, modern fisheries survey methods were adopted in 1993 so data from this year on were collected using similar methods. Older fisheries and water quality data are available; however, in this study these data were only used as part of the use designation review for these lakes (see Appendix C). Methods for MNDNR's fisheries surveys are described briefly below with more detailed descriptions in MNDNR (2017).

Standard gill net surveys: Fisheries surveys were conducted from February through November, but more than 95% of surveys were conducted in between June and September. Gear for standard gill net surveys consisted of 250 ft (76.2 m) long by 6 ft (1.8 m) deep nets constructed of five 50-ft-long (15.2 m) panels of white multifilament knotted-nylon mesh. The panels had mesh sizes (bar measure) of 0.75 in (1.9 cm), 1.0 in (2.5 cm), 1.25 in (3.2 cm), 1.5 in (3.8 cm), and 2.0 in (5.1 cm) and were ordered from small to large. The nets were set on the lake bottom, with brails and anchors at each end of the net to hold it taut and open. In some cases, a rope harness with added flotation at the top was substituted for the brail. Standard sets were deployed overnight or for about 24 hours. Where set locations were established, they were repeated in subsequent surveys whenever possible. For new sampling stations, locations were selected to include a variety of habitats, and the orientation of mesh sizes with respect to the shoreline was alternated. Where possible, nets were set perpendicular to shore and in waters deeper than nine ft (1.8 m) to avoid outboard motors. Before setting gill nets, a temperature-oxygen profile was measured to avoid setting nets in anoxic waters.

Coldwater fish species may not be targeted in some of the MNDNR's standard fisheries surveys. In many surveys, nets are set along the lake bottom in depths at or above the thermocline, rather than in pelagic areas. Consequently, standard gill net methods may not effectively sample coldwater fish for population studies (e.g., abundance measures may not be reliable for these data). However, in lakes known to support, or suspected of supporting a coldwater fish community, standard gill net sets, or portions of gill net sets, may be set deeper (i.e., below the thermocline). This practice is most common in north-eastern

Minnesota lakes, which coincides with the portion of the state with the largest number of lakes supporting coldwater fishes. Standard MNDNR fisheries surveys consist of a mix of survey methods that may or may not target coldwater fishes which do not provide precise estimates of abundance or other population metrics (Siesennop 1998). However, coldwater fishes are captured using these methods and these data can be used to at least determine species' presence or absence (Jacobson et al. 2010).

Data were available which used methods that differed from the MNDNR's standard survey. This included vertical gill net surveys which specifically target coldwater fishes. Vertical gill net gear was typically deployed to evaluate presence and size and depth distributions of coldwater fish and for use in conjunction with hydroacoustic surveys to estimate density and biomass. Vertical gill net gangs, comprised of seven panels of monofilament webbing ranging from 0.375 in (1.0 cm) to 1.75 in (4.4 cm) bar measure, were deployed during summer stratification (mid-June through mid-September) and were set in the deepest portion of the lake basin. Nets were set from the surface to the bottom such that the entire water column was covered. In simple lake basins, a single gang of nets was set and in more complex basins, multiple gangs of nets were set with a maximum of three nets per lake. As with standard gill net sets, a temperature-oxygen profile was measured. Nets were deployed overnight for a total duration of about 24 hours. A detailed description of the equipment used for vertical gill net surveys is provided in MNDNR (2017). Data from vertical gill net surveys were used to supplement standard MNDNR fisheries surveys.

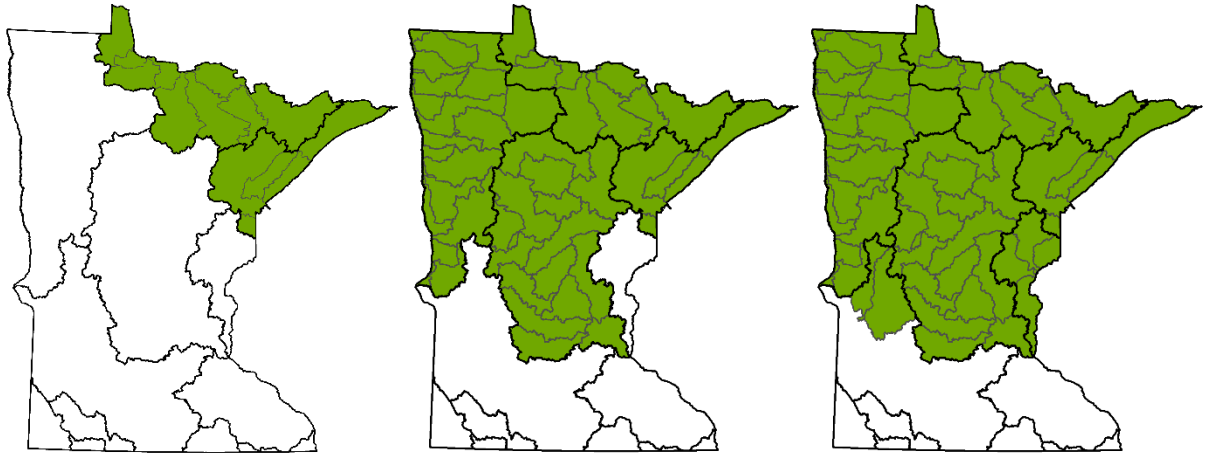
d. Lake filters

Data compilation for threshold analyses was focused on pairing coldwater fish survey data with stressor measures (i.e., T_{DO3} and chl-*a*) from lakes where these fish species could occur. The goal for developing this dataset was to identify lakes with the potential to support populations of coldwater fish based on lake morphology and biogeography. The distribution of extant populations of these fishes could then be made along a gradient of modern water quality data. Three filters were used to select lakes for analyses: species range, population status, and lake stratification.

Coldwater fish species range: To select lakes where coldwater fish are more likely to occur independent of water quality, biogeography and lake typology were considered. Lakes from watersheds and regions where these fish are considered to be native and are extant were selected for inclusion in the dataset. This is largely based on reported distributions in Hatch (2015) and then further refined based on current distribution of lakes where these fish are native or possibly native and extant. See ***Minnesota's coldwater fishes*** for additional details. The maps in Figure 3 indicate the watersheds from which lakes were selected for these analyses.

Coldwater fish species population status: Lakes with transient or extirpated populations of coldwater fishes were excluded from most analyses. Lakes with transient populations were removed because conditions in these lakes appear to not be suitable for long-term maintenance of coldwater fish populations and the inclusion of these lakes could impact analyses by indicating that the water quality conditions in these lakes were suitable to support coldwater fishes. Lakes with extirpated populations of coldwater fishes were removed because our analysis did not include temporal considerations, and the inclusion of these lakes could have indicated that coldwater fishes could be maintained under current water quality conditions even though the opposite was likely true. In addition, the number of lakes with extirpated populations of coldwater fishes was relatively small and their exclusion was unlikely to impact analyses. This status was determined through consultation with MNDNR area fisheries offices using fisheries survey data, lake morphology data, and other evidence. For example, a small number of large Lake Whitefish sampled in a lake with a connection to a lake with an extant, reproducing Lake Whitefish population, would likely be removed because these fish are likely not resident. See ***Coldwater lake habitat use designation reviews*** for additional details.

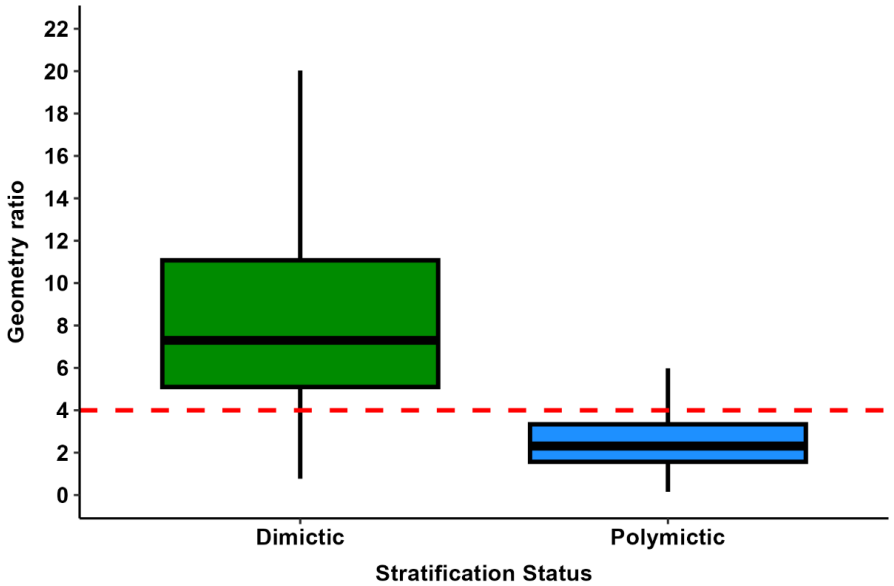
Figure 3. Watershed subbasin (8-digit hydrologic unit codes [HUC 8]) distributions of coldwater fish species in Minnesota based on current distributions of these species.



Lake Trout **Lake whitefish** **Cisco**

Lake stratification: Lakes were divided into dimictic and polymictic lakes using geometry ratio. Geometry ratio is calculated as: $A_0^{0.25}/z_{max}$, where A_0 is lake surface area (m^2) and z_{max} is maximum depth (m) (Stefan et al. 1996). A geometry ratio of 4 was used as a threshold to predict lake stratification where lakes with a geometry ratio of less than 4 were identified as dimictic. A geometry ratio 4 was selected as a threshold because it reasonably distinguishes between dimictic and polymictic lakes (Figure 4). Jacobson et al. (2010) also determined that there is little effect of geometry ratio on T_{DO3} for lakes with a geometry ratio above 4 indicating a transition between dimictic and polymictic lakes. Most analyses in this report use only lakes with a geometry ratio of less than 4. See ***Coldwater lake habitat use designation reviews*** for additional details.

Figure 4. Comparison of geometry ratio for dimictic and polymictic lakes. Dimictic lakes were determined to be lakes with a temperature gradient of at least 1 °C per meter for more than 50% of lake oxythermal profiles (June through September). Red dashed line indicates threshold used to predict lake stratification type.



e. Threshold analyses

Several analyses were used to determine thresholds for oxythermal habitat and eutrophication. These analyses were used both as supplemental evidence and to directly identify protective conditions for coldwater fishes. The probability of lakes supporting coldwater fish species as a function of T_{DO3} or chl-*a* was modeled using logistic regressions[8]. Generalized additive models using a logistic link function were fit to presence absence data for each species in R ver. 4.3.1 (R Development Core Team 2023) with the "gam" function ("mgcv" package; Wood 2011). To determine oxythermal and chl-*a* thresholds for each of the three coldwater fish species, the 95th percentile of the observed occurrence for each coldwater fish species were calculated using abundance weighted cumulative distribution functions. These values are referred to as extirpation (XC_{95}) values and are modified from methods in Cormier and Suter (2013). In Cormier and Suter (2013), 95th percentiles were used to determine XC values for multiple taxa which were aggregated to determine benchmarks for a stressor. This threshold is consistent with laboratory-based methods for determining toxicity where the intent is to protect 95% of taxa (Cormier and Suter 2013). Cormier and Suter (2013) selected the 95th percentile because it is more stable than a maximum value, but still represents the upper range of a taxon's tolerance to a stressor. Here the 95th percentile was used to determine protective thresholds for single coldwater fish species. To assess the performance of oxythermal and chl-*a* thresholds, receiver operating characteristic (ROC) curves were modeled in R version 4.3.1 (R Development Core Team 2023) using the "pROC" package (Robin et al. 2011). Area under the curve (AUC) scores were used to evaluate each ROC model. For this analysis, an AUC value of 1 indicates that the model perfectly predicts the occurrence of a fish species and a score of 0.5 indicates that it has no predictive ability. Scores between 0.5 and 1 indicate different levels of predictive ability for the models, but there is no absolute threshold which indicates whether a model is good or not. Hosmer et al. (2013) assigned approximate guidelines for AUC values[9] which we follow here to provide some context. Error rates for predicting the occurrence of coldwater fish species were plotted as a function of T_{DO3} thresholds. These plots were generated because these error rates can provide insight into the performance of the draft T_{DO3} criteria.

ii. Oxythermal criteria for the protection of coldwater fish species

a. Analysis of oxythermal habitat metrics

Coldwater fish species in Minnesota's lakes require cool, well-oxygenated water for survival. During the summer in most dimictic lakes, the habitat which meets the requirements for these fish species is limited to only a portion of the water column (see Figure 1). Typically, the upper layer (i.e., epilimnion) has sufficient dissolved oxygen, but is too warm for coldwater fish. Although the hypolimnion is typically cool enough, it may also be unsuitable due to dissolved oxygen depletion. As a result, the only suitable habitat for coldwater fish may be in the metalimnion or upper portion of the hypolimnion where dissolved oxygen and water temperature are suitable.

The most important factors influencing oxythermal habitat in Minnesota lakes include lake stratification type (i.e., morphology), lake trophic status, and air temperature (Jacobson et al. 2010). In Minnesota, most lakes which support coldwater fishes stratify during the summer which maintains cool water below

[8] **T_{DO3} logistic models:** gam(cisco presence ~ s(T_{DO3}, bs="tp", k=10), family=binomial(logit), method="REML"); gam(Lake Whitefish presence ~ s(T_{DO3}, bs="tp", k=10), family=binomial(logit), method="REML"); gam(lake trout presence ~ s(T_{DO3}, bs="tp", k=7), family=binomial(logit), method="REML")
Chlorophyll-*a* logistic models: gam(cisco presence ~ s(chl-*a*, bs="tp", k=3), family=binomial(logit), method="REML"); gam(Lake Whitefish presence ~ s(chl-*a*, bs="tp", k=3), family=binomial(logit), method="REML"); gam(lake trout presence ~ s(chl-*a*, bs="tp", k=10), family=binomial(logit), method="REML");

[9] AUC discrimination guidelines from Hosmer et al. (2013): 0.5-0.7 = poor; 0.7-0.8 = acceptable; 0.8-0.9 = excellent; >0.9 = outstanding

the epilimnion. These lakes are typically deep with a sufficient volume of cool water below the epilimnion to provide habitat and dissolved oxygen for coldwater fish. There are also some polymictic lakes in Minnesota that also support coldwater fish, but most of these lakes are in northern Minnesota where air temperatures are cool enough to maintain cool water temperatures throughout much of the water column. Some lakes that do not stratify or which lack well-oxygenated water below the epilimnion may support coldwater fish due to refugia such as springs or other site-specific conditions (e.g., Ryan and Marshall 1994, Snucins and Gunn 1995).

The productivity of a lake affects oxygen availability in the hypolimnion. More productive or enriched lakes have lower hypolimnetic dissolved oxygen and less available habitat for coldwater fishes due to greater oxygen demand in sediment and the hypolimnion (Sharma et al. 2011, Müller et al. 2012, Havens et al. 2014). Some lakes may not support coldwater fish habitat due to natural productivity levels or cultural eutrophication may elevate productivity to the point that coldwater fish habitat is lost. Air temperature largely controls warming of lakes and is affected by weather, climate, and day of the year. Warmer air temperatures increase water temperature in the upper layers of the lake and shrinks available habitat for coldwater fishes by forcing these fish to move deeper to find cool water. Temperature also has interactive effects with productivity and dissolved oxygen level because warmer temperatures can expand growing seasons and increase growth rates and respiration.

Oxythermal requirements for coldwater fishes are complicated because other than under extreme conditions, there are not absolute values for temperature or oxygen which are lethal. Rather optimal, preferred, stressful, and lethal conditions for these fish vary depending on these and other variables. For example, at lower water temperatures, coldwater fish can survive at lower dissolved oxygen levels than they can at higher water temperatures (Jacobson et al. 2008). As a result, it is necessary to consider both oxygen and water temperature when developing water quality thresholds for coldwater fishes.

To analyze the specific requirements for Minnesota's coldwater fishes, both dissolved oxygen and temperature were considered. This was accomplished using the oxythermal habitat measure T_{DO3} (i.e., the temperature at which dissolved oxygen is 3 mg/L; see Figure 2). This endpoint has been used in other research of coldwater fishes in Minnesota lakes (e.g., Jacobson et al. 2010, Fang et al. 2012, and Jiang et al. 2017). Other studies have used different endpoints such as T_{DO6} or a layer which meets oxygen and thermal criteria (e.g., Lyons et al. 2017, EPA 2021). Lyons et al. (2017) determined that a 1 m layer with a T_{DO6} of 22.8 °C (i.e., dissolved oxygen ≥6 and temperature ≤22.8 °C) was needed to protect Cisco. The metric T_{DO6} was selected to align this threshold with existing coldwater standards in Wisconsin. Different T_{DOx} endpoints do not necessarily indicate preferential or lethal dissolved oxygen concentrations or temperatures for these coldwater fish. As a result, different endpoints can be used to develop similarly protective thresholds although the values identified will be different. This is because T_{DOx} consists of both a dissolved oxygen and a temperature target and by modifying one of these, the other is also altered. For example, changing the dissolved oxygen target from 6 mg/L to 3 mg/L will lower the protective temperature target and result in a different, but similarly protective T_{DOx} threshold. An exception to this would be using extreme measures of dissolved oxygen or temperature which result in interpolated values outside normal conditions in lakes or well outside the ecological requirements for these fish.

Over the course of a summer season, the T_{DO3} in a lake will change because of seasonal climatic patterns and weather. As a result, it is important to determine the period of maximum oxythermal stress in these lakes. Using the same methods from Jacobson et al. (2010), we repeated this analysis with our data to assess if similar results would be obtained. Generalized additive models (GAM) were fit to T_{DO3} data as a function of the geometry ratio, day of year, total phosphorus, July air temperature, and year in R ver. 4.3.1 (R Development Core Team 2023) using the "gam" function ("mgcv" package; Wood 2011). This analysis included statewide profile and total phosphorus data for lakes sampled from 1990-2020. The

effect of these factors on T_{DO3} was analyzed for both polymictic (geometry ratio ≥4) and dimictic (geometry ratio <4) lakes to determine the 30 days of maximum oxythermal stress (i.e., the period with the highest T_{DO3} values). Geometry ratio, day of the year, and total phosphorus had the largest effects on T_{DO3} in dimictic lakes. July air temperature and year had weakly positive effects on T_{DO3}. In polymictic lakes, the day of the year also had a strong effect on T_{DO3}, but the effects of geometry ratio and total phosphorus were weaker. In contrast, July air temperature and year had a stronger effect on T_{DO3} in polymictic compared to dimictic lakes. This analysis identified the period from July 26 through August 24 for dimictic lakes (Figure 5) and July 11 through August 10 for polymictic lakes (Figure 6) as periods of highest oxythermal stress. Although our datasets differ, these results largely confirm those of Jacobson et al. (2010) which identified July 27 through August 26 for dimictic lakes and July 13 through August 12 for polymictic lakes as periods of highest oxythermal stress. The following analyses in this study use only oxythermal data from July 26 through August 24 unless otherwise noted. The effects of geometry ratio, total phosphorus, and July air temperature were also similar to that of Jacobson et al. (2010). Unlike Jacobson et al. (2010), we also included year to determine if there was a trend in the oxythermal conditions over time during this study period. Our results, indicate a weak positive trend in dimictic lakes and a stronger positive trend in polymictic lakes. For the dimictic lakes, the weak trend indicates that the dataset is representative of lake oxythermal conditions during this period.

Figure 5. Effect of A) geometry ratio, B) day of year, C) total phosphorus, D) July air temperature, and E) year on oxythermal habitat (T_{DO3}) for dimictic (geometry ratio <4) lakes (1990-2020). Fit: generalized additive model (GAM; bs = "tp", method = "REML"); shaded area: ±2 standard error; vertical dotted lines bracket the 30 days of highest oxythermal stress.

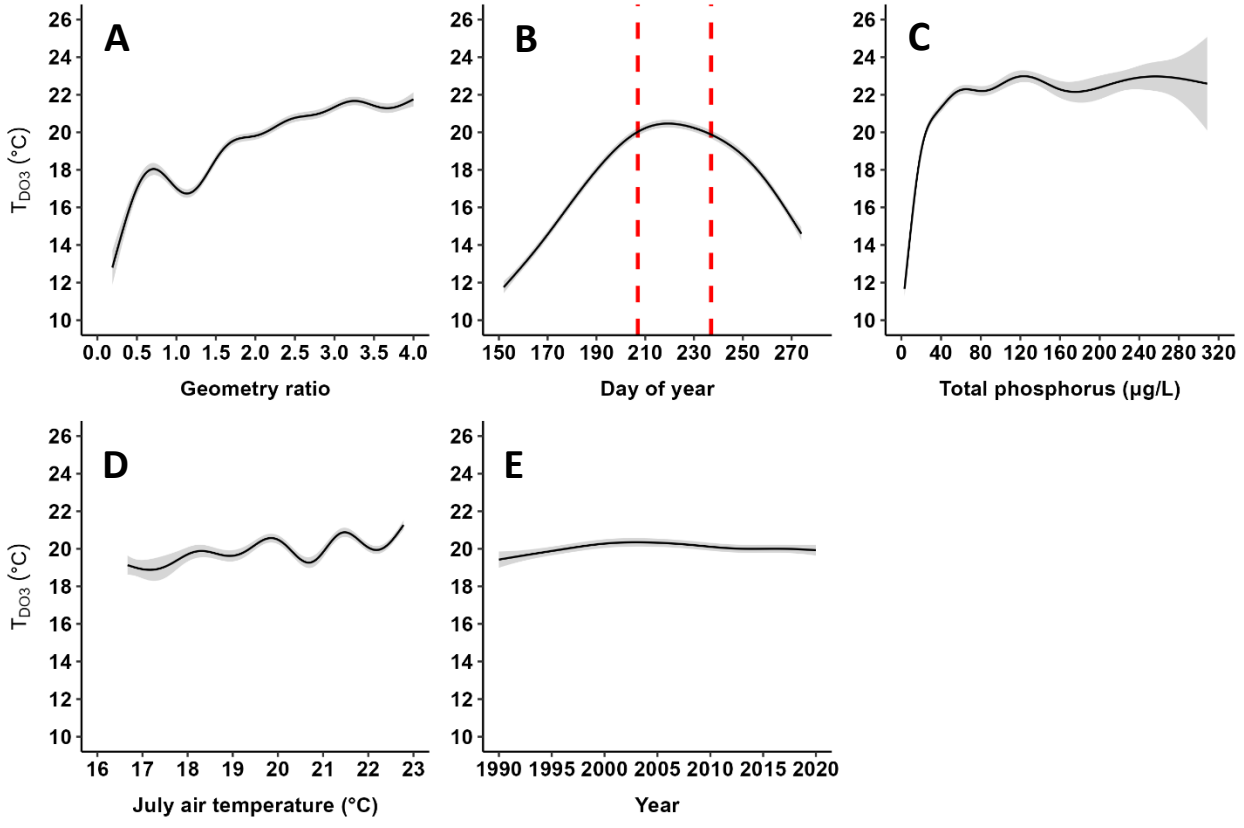
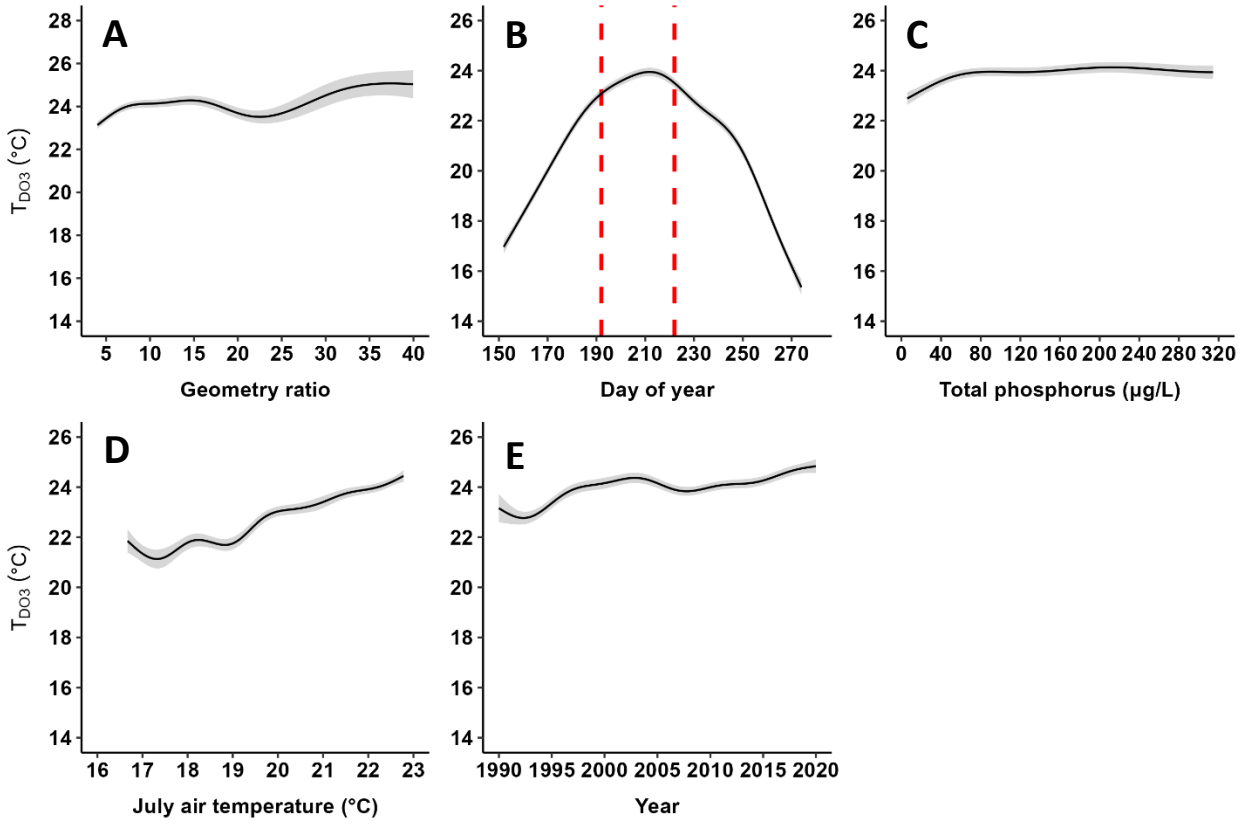
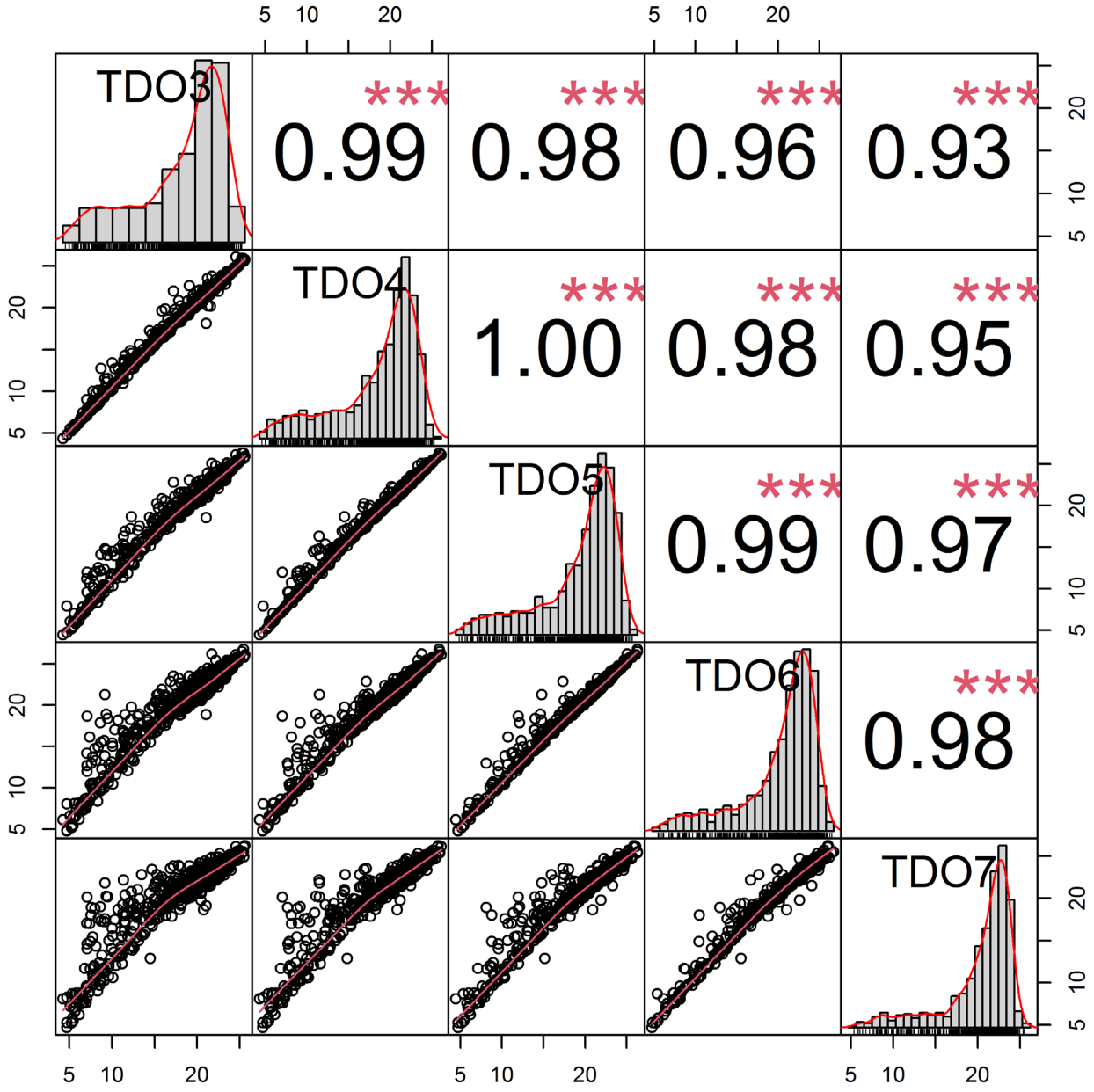


Figure 6. Effect of A) geometry ratio, B) day of year, C) total phosphorus, D) July air temperature, and E) year on oxythermal habitat (T_{DO3}) for polymictic (geometry ratio >4) lakes (1990-2020). Fit: generalized additive model (GAM; bs = "tp", method = "REML"); shaded area: ±2 standard error; vertical dotted lines bracket the 30 days of highest oxythermal stress.



In general, oxythermal measures are comparable when using normoxic (e.g., 30-100% saturation) dissolved oxygen endpoints. Different oxythermal measures are highly correlated based on Spearman correlations (Figure 7) although the relationship is slighter weaker for more distant measures (e.g., T_{DO3} and T_{DO7}). Use of a higher dissolved oxygen threshold also results in more scatter in the relationship in lakes with lower oxythermal values. This indicates that these lakes maintain normoxic conditions in the hypolimnion, but not high dissolved oxygen (e.g., 6 or 7 mg/L) concentrations (Figure 7). The oxythermal environment to which a fish is exposed is dependent on many factors including the accessible habitat within a lake, the location of prey or predators, the oxythermal preference of fish (as affected by life stage, age, and genetics), and the effect of acclimation. Although the relationship of coldwater fish to oxythermal endpoints is complex, in general, coldwater fish seem to seek the coldest habitat where dissolved oxygen requirements are met when lakes are stratified. As dissolved oxygen is depleted in the hypolimnion and metalimnion, coldwater fishes move higher in the water column where they are usually exposed to warmer water. When minimum dissolved oxygen concentrations for these fishes are found in waters exceeding the upper thermal limits in a lake, mortality events will occur. If these events are severe or frequent, it will result in the extirpation of the population.

Figure 7. Correlation matrix (Spearman's) of oxythermal measures for dimictic lakes (geometry ratio <4) in Minnesota.



b. Analysis of coldwater fish and oxythermal habitat

Using similar methods to those in Jacobson et al. (2010), an expanded dataset of Minnesota coldwater fishes was analyzed using logistic regression analysis. All three species had a negative relationship between their probability of occurrence and T_{DO3} with each exhibiting a different pattern in this relationship (Figures 8 and 9). These patterns largely match those reported in Jacobson et al. (2010). Cisco were the most eurythermic species with the steepest decline in presence occurring above 21 °C. Lake Whitefish were more sensitive to oxythermal habitat, although there was no distinct threshold along the gradient. Lake Trout were the most stenothermic with a steep decline in their occurrence above 8 °C. These relationships demonstrate the negative effects of high T_{DO3} on these species and provide some estimates of thresholds for at least Cisco and Lake Trout.

Figure 8. Probability of the occurrence of A) Cisco, B) Lake Whitefish, C) Lake Trout, and D) all three species (solid line = Cisco, dashed line = Lake Whitefish, dotted line = Lake Trout) as a function of average oxythermal habitat (T_{DO3}). Fit is a generalized additive model (GAM) logistic regression (bs = "tp", method = "REML", k =10 [Cisco, Lake Whitefish], 7 [Lake Trout]). Shaded area: 90% confidence interval. Datasets include only lakes with at least two fisheries surveys and three years of oxythermal profiles.

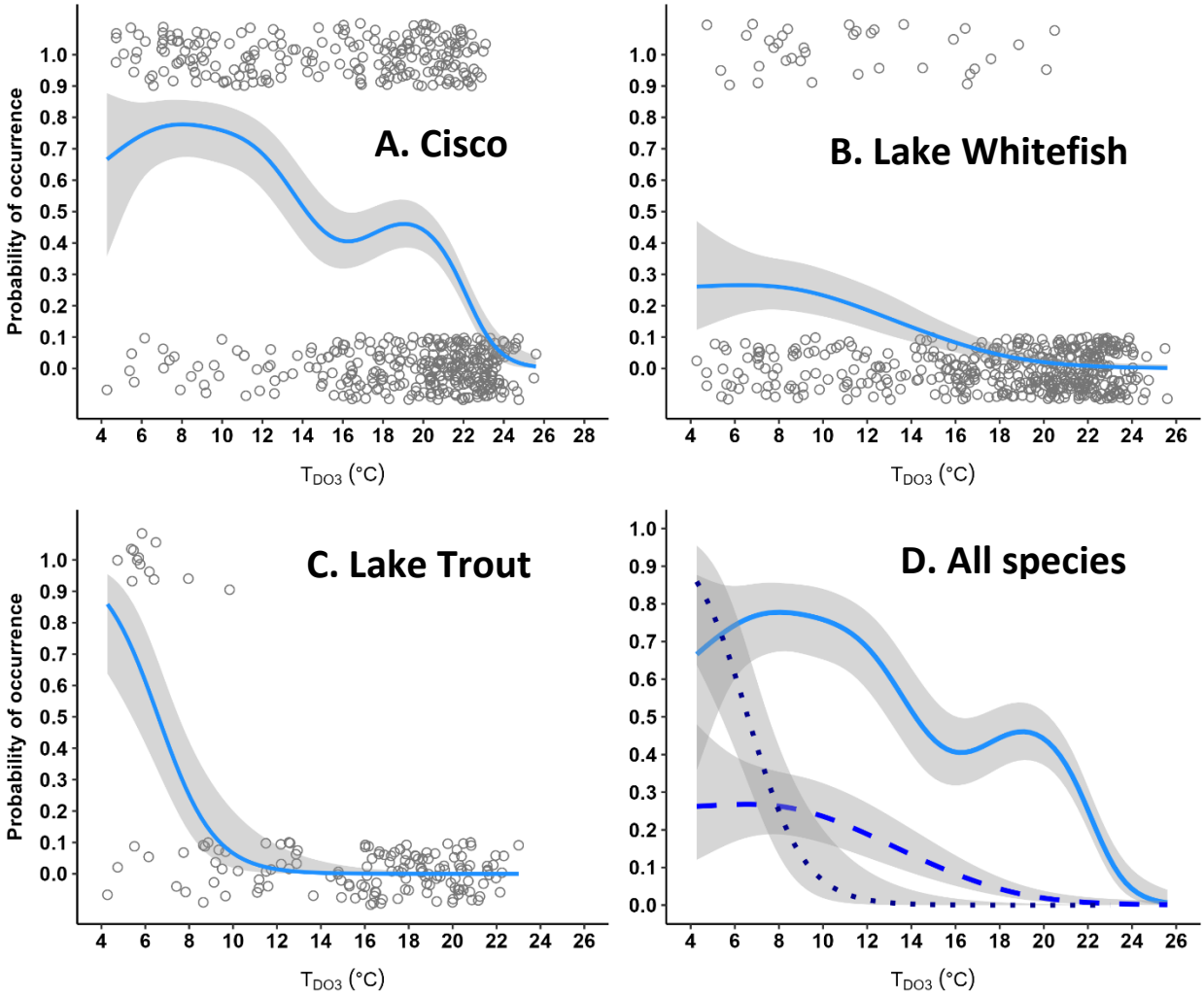
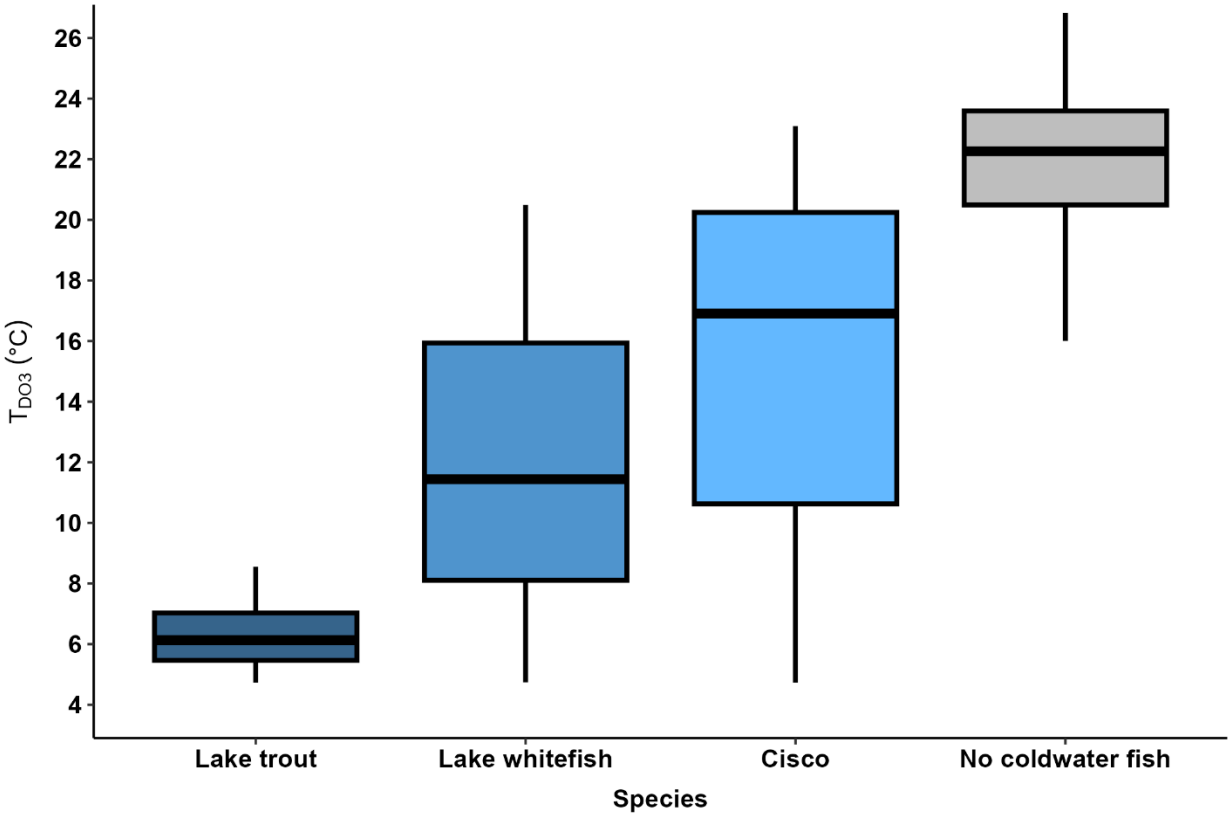


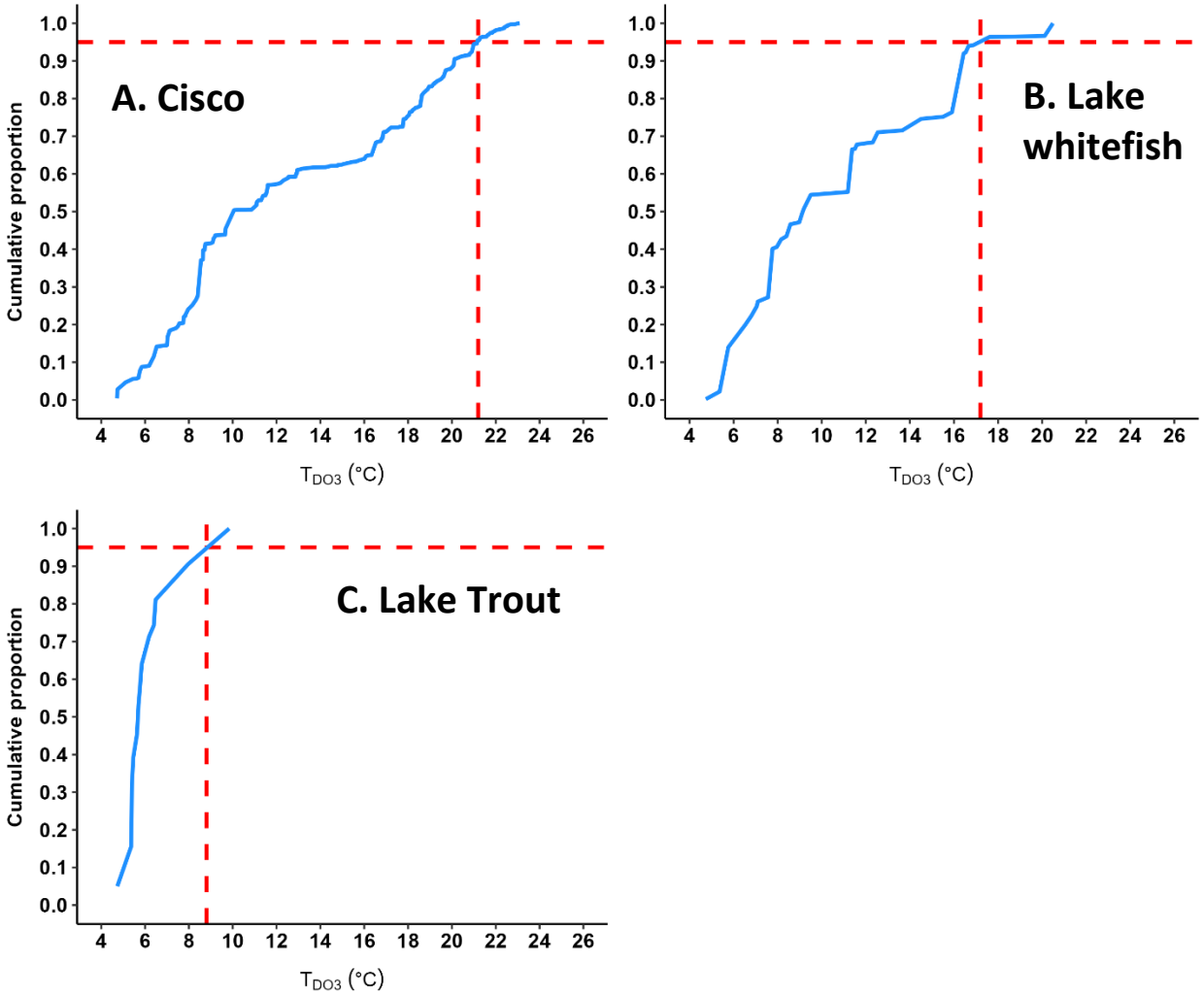
Figure 9. Box plots of average T_{DO3} for lakes supporting coldwater fish species. Description of box plots: lower hinge = 25th percentile; upper hinge = 75th percentile; whiskers = 1.5 x interquartile range.



c. Oxythermal habitat threshold development

Minimum oxythermal thresholds for the protection of coldwater fish species were determined from abundance-weighted cumulative distribution functions. These T_{DO3} thresholds were determined by calculating 95th extirpation (XC_{95}) values for each coldwater fish species. These datasets consisted of lakes which were determined to support resident populations of these these coldwater fishes (see Appendix C). Analysis of species occurrence error rates along with the results of the previous section were also used to support these criteria. As demonstrated in previous analyses, XC_{95} values were different for the three fish species analyzed with increasing tolerance from Lake Trout to Lake Whitefish to Cisco (Figure 10). The XC_{95} was 21.2 °C for Cisco, 17.2 °C for Lake Whitefish, and 8.8 °C for Lake Trout (Figure 10). These values largely match observations from the logistic regression analyses (Figure 8).

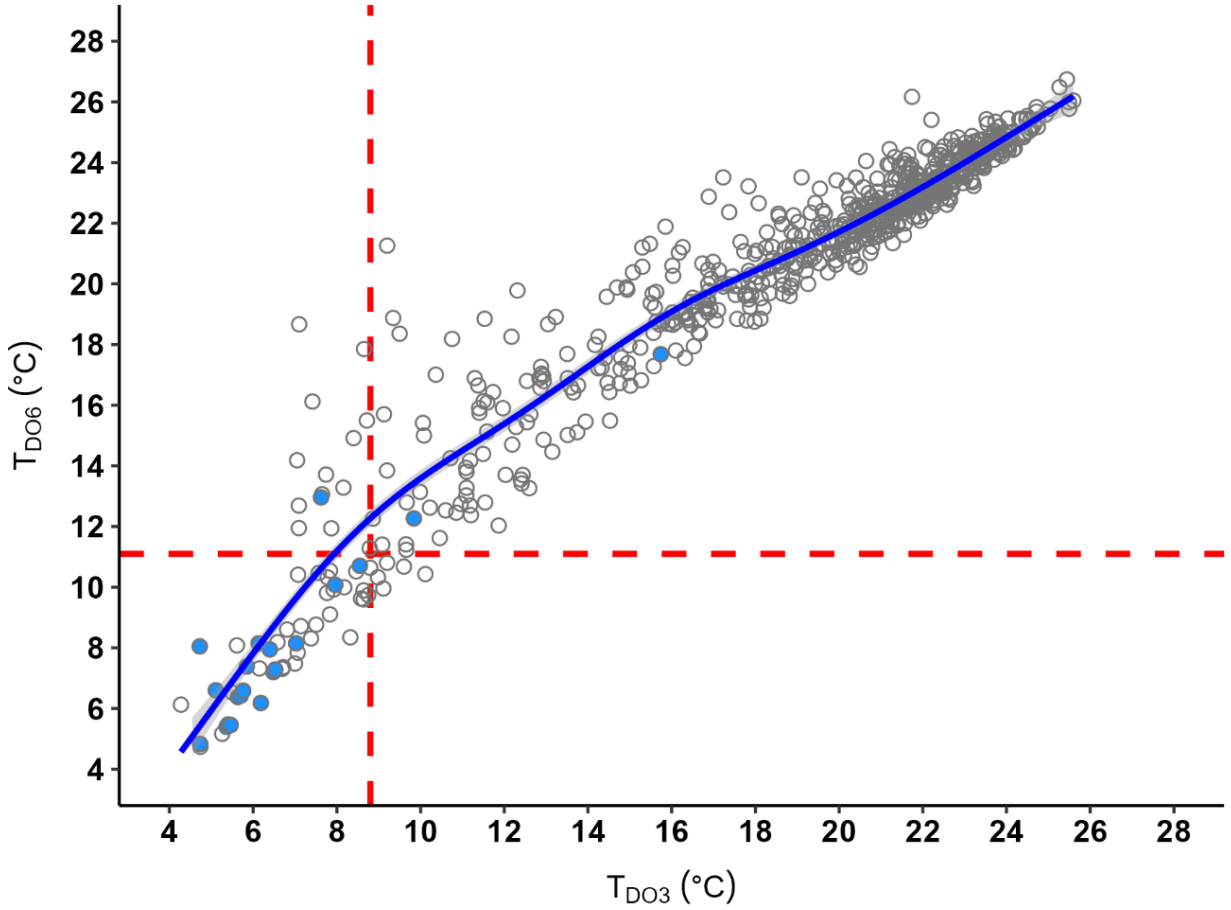
Figure 10. Average abundance weighted cumulative distribution functions for T_{DO3} for A) Cisco, B) Lake Whitefish, and C) Lake Trout. Red dashed line: 95th percentile extirpation value.



To confirm the use of T_{DO3} as a reasonable metric for Lake Trout, this oxythermal measure was compared against T_{DO6}. These two measures are highly correlated (ρ = 0.96; Figure 7). An abundance-weighted XC_{95} for Lake Trout based on T_{DO6} is 11.1 °C compared to 8.8 °C for T_{DO3}. The plot of T_{DO3} and T_{DO6} indicates that regardless of the oxythermal measure, attainment of XC_{95}-based thresholds is similar (Figure 11). There was a single lake where absolute oxythermal measures indicated that assessment outcomes could be different. In this lake, oxythermal measures were within 2 °C of thresholds indicating coldwater habitat near marginal conditions. The MNDNR stocks Lake Trout in this lake (East Bearskin [16-0146-00]) and there is indication that there is natural reproduction. Therefore, this lake appears to currently sustain a Lake Trout population and although it is augmented through stocking, oxythermal conditions appear to be suitable. This indicates that T_{DO3} may be providing a more accurate assessment of Lake Trout habitat in this lake compared to T_{DO6}. Due to this specific example and the overall high correlation between these and other oxythermal measures, the use of T_{DO3} appears to be a suitable measure for Lake Trout habitat regardless of the results of studies determining lethal temperatures or dissolved oxygen concentrations. Although coldwater fishes may have different oxygen requirements, the same dissolved oxygen endpoint can be used as part of an oxythermal measure to develop protective criteria. Such fixed thresholds do not necessarily translate to optimal or lethal oxythermal thresholds for each species, but they can be used to measure the suitability of habitat within a lake when the oxythermal measure is linked to fish population health endpoints. However, as part of

assessments, it may be useful to examine different oxythermal measures to better characterize coldwater habitat in lakes when a lake is near the threshold.

Figure 11. Relationship between average T_{DO3} and T_{DO6} for dimictic lakes (geometry ratio < 4) with at least 3 years of T_{DOx} data (1990-2020). Fit is a generalized additive model (GAM) logistic regression (bs = "tp", method = "REML", k =10). Shaded area: 90% confidence interval; red dashed lines: XC_{95} for Lake Trout; blue points: Lake Trout lakes; open points: non-Lake Trout lakes.



To evaluate how well T_{DO3} predicts the presence of coldwater fishes, ROC curves were modeled and evaluated using AUC scores. For the three coldwater fish species assessed, the discrimination ability of models to predict species occurrence based on T_{DO3} ranged from acceptable to outstanding (Figure 12). The Lake Trout model performed best with an AUC value of 0.9698 indicating that most lakes in in the dataset with a T_{DO3} below 8.8 °C support Lake Trout. T_{DO3} is also highly predictive of the occurrence of Lake Whitefish although the relatively small number of lakes supporting Lake Whitefish in Minnesota increases prediction error (Figure 12). The prediction of the occurrence of Cisco using T_{DO3} was acceptable. The largest error associated with predicting coldwater fish presence based on oxythermal habitat, especially for Lake Whitefish and Cisco, was due to many lakes with apparently suitable oxythermal habitat which do not support coldwater fishes (Table 10). The exact characteristics that make many of the lakes with good T_{DO3} unsuitable for Lake Whitefish or Cisco is not discernable from the analyses in this report. It could be due to local biogeography or other lake-specific habitat characteristics that make these lakes unsuitable for these fish species. However, these analyses support the draft T_{DO3} thresholds and indicate that these oxythermal thresholds have low (~10-20%) false negative rates (i.e., predicting that a lake does not support coldwater fish species when in fact it does; Figure 12).

Figure 12. Receiver operating characteristic (ROC) curves (top row) and cut-off plots (bottom row) using T_{DO3} as a predictor of species occurrence for A) Cisco (AUC = 0.7375), B) Lake Whitefish (AUC = 0.8425), and C) Lake Trout (AUC = 0.9696). For receiver operating characteristic curves, specificity refers to the true negativity rate and sensitivity refers to the true positivity rate. For error rate plots, solid lines are false negatives and dashed lines are false positives.

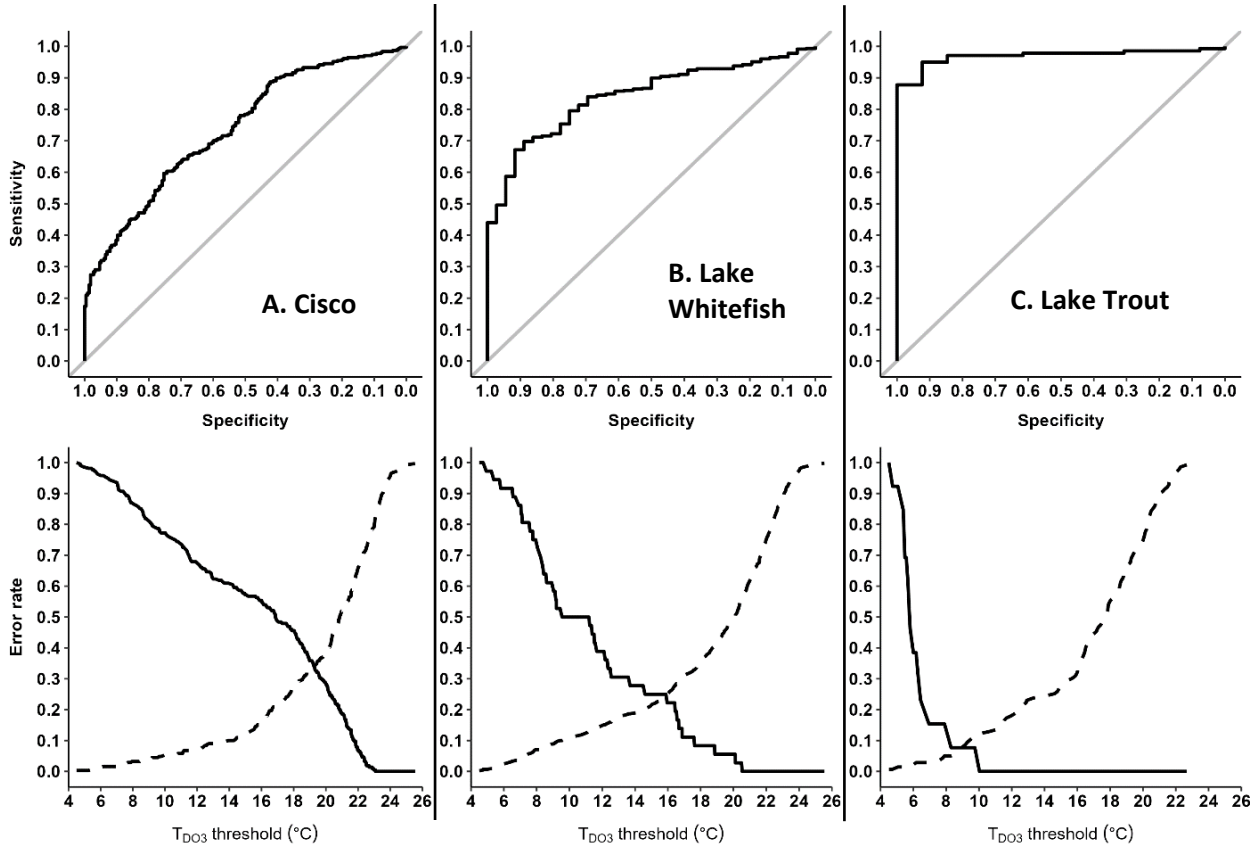


Table 10. Confusion matrices for predicting coldwater fish presence based on T_{DO3} 95th percentile extirpation thresholds determined from abundance-weighted cumulative distributions. Percentages are the proportion of lakes where the presence or absence of coldwater fishes was correctly or incorrectly predicted based on the draft standards. Blue cells are correct predictions and orange cells are incorrect predictions.

Confusion matrices		
Cisco	**T_{DO3} exceeds**	**T_{DO3} meets**
Fish absent	146 (28%)	164 (31%)
Fish present	36 (7%)	179 (34%)
Lake Whitefish	**T_{DO3} exceeds**	**T_{DO3} meets**
Fish absent	307 (63%)	143 (29%)
Fish present	4 (1%)	32 (7%)
Lake Trout	**T_{DO3} exceeds**	**T_{DO3} meets**
Fish absent	129 (85%)	10 (7%)
Fish present	1 (1%)	12 (8%)

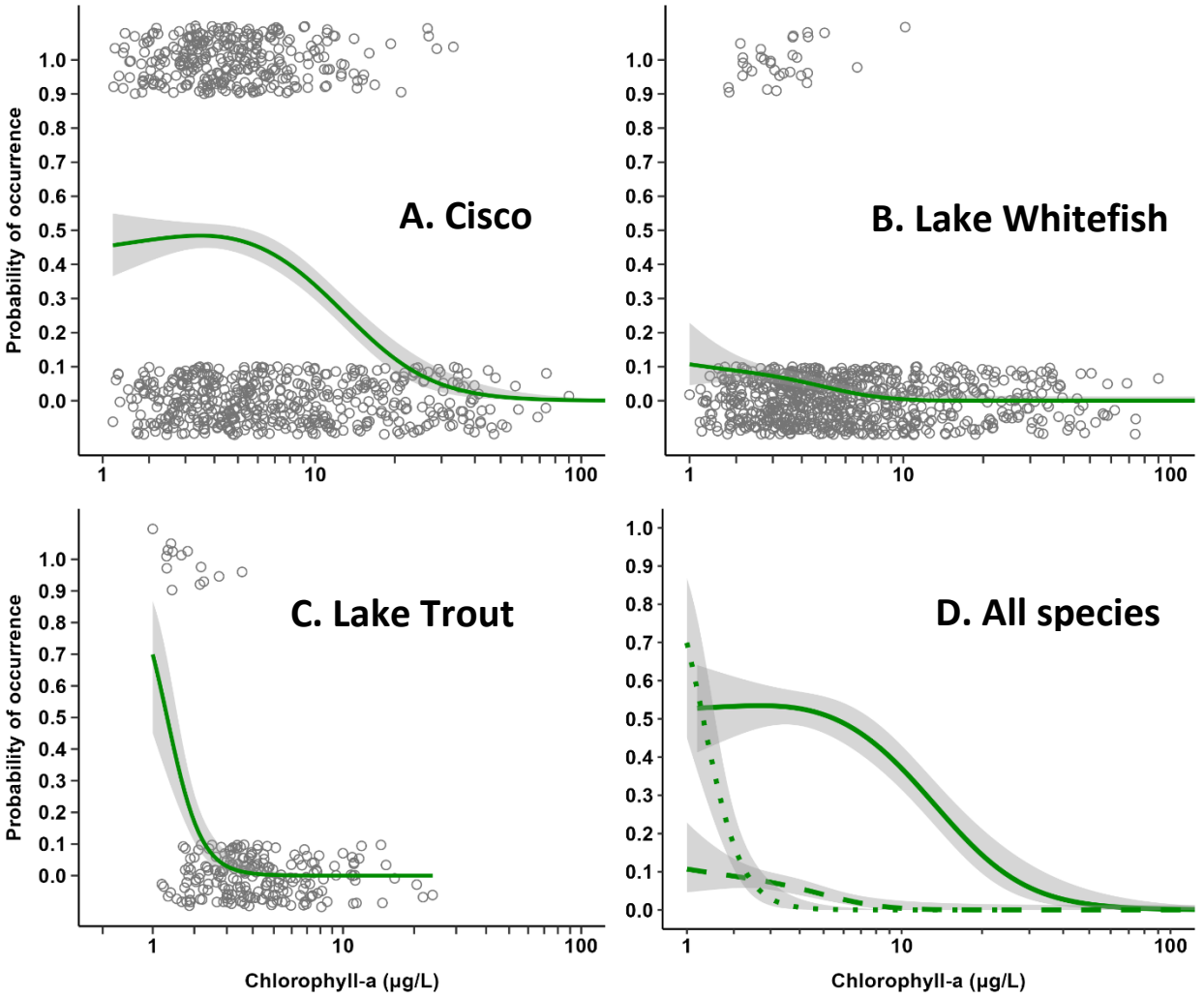
iii. Eutrophication criteria for the protection of coldwater fish species

a. Analysis of coldwater fish and chlorophyll-a

Nutrient levels and lake productivity directly influence the depletion of dissolved oxygen in the hypolimnion of lakes during the summer (Walker 1979, Molot et al. 1992, Clark et al. 2002, Clark et at. 2004). As with T_{DO3}, the presence of coldwater species was analyzed as a function of chl-*a*. Generalized

additive models using a logistic link function were run for chl-*a*. As with T_{DO3}, all three species had a negative relationship between the probability of occurrence and chl-*a* with each exhibiting a different pattern in this relationship (Figure 13). Cisco were the most tolerant species with a decline in presence occurring above a chl-*a* concentration of 10 µg/L. Lake Whitefish were more sensitive to oxythermal habitat with their probability of occurrence declining at chl-*a* concentrations of 3-4 µg/L. However, in this dataset, Lake Whitefish lakes were uncommon, and the probability of occurrence was low along the gradient. Lake Trout were the most sensitive with a decline in their occurrence above chl-*a* concentration of 1 µg/L. These relationships demonstrate the negative effects of high chl-*a* on these species and provide some estimates of thresholds.

Figure 13. Probability of occurrence for A) Cisco, B) Lake Whitefish, C) Lake Trout, and D) all three species (solid line = Cisco, dashed line = Lake Whitefish, dotted line = Lake Trout) as a function of chlorophyll-*a*. Fits are generalized additive model (GAM) logistic regressions (bs = "tp", method = "REML", k = 3 [Cisco, Lake Whitefish], 10 [Lake Trout]). Shaded area: 90% confidence interval.

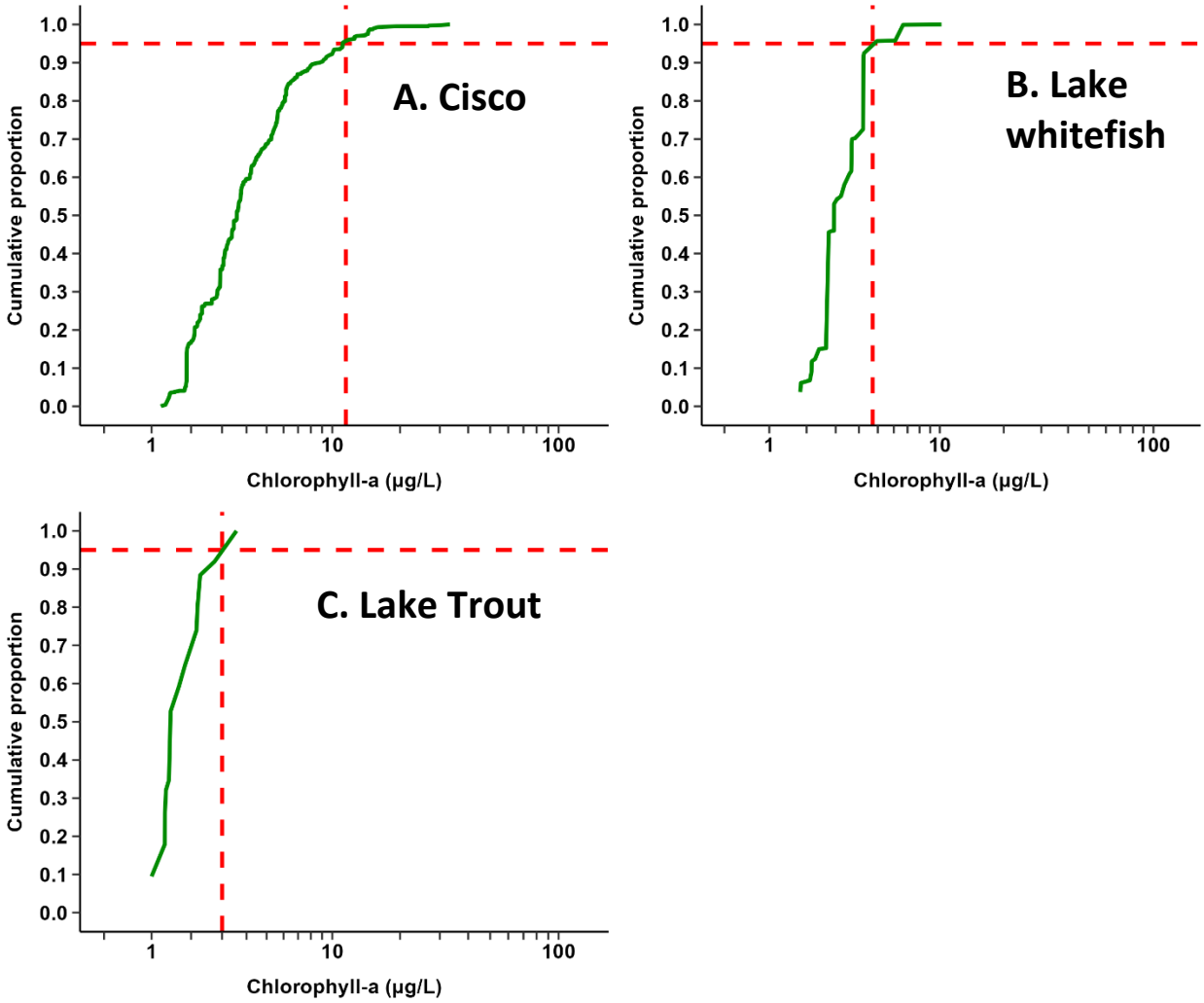


b. Chlorophyll-a threshold development

Minimum chl-*a* thresholds for the protection of coldwater fish species were determined from abundance weighted cumulative distribution functions. These datasets consisted of lakes which were determined to support resident populations of these these coldwater fishes (see Appendix C). Ninty-five percent extirpation values (XC_{95}) for chl-*a* were calcuated and resulted in thresholds of 12 µg/L for Cisco, 5 µg/L for Lake Whitefish, and 3 µg/L for Lake Trout (Figure 14). These values largely match observations

from the logistic regression analyses (Figure 13) although they are somewhat higher. The Lake Trout threshold is consistent with the results of Ryan and Marshall (1994) which determined that most lakes supporting Lake Trout had chl-*a* below 3 µg/L (corresponding to predicted oxygen depletion levels of <40%). In addition, 3 µg/L matches Minnesota's existing standard for Lake Trout lakes.

Figure 14. Average abundance weighted cumulative distribution functions for chlorophyll-*a* for A) Cisco, B) Lake Whitefish, and C) Lake Trout. Red dashed line: 95th percentile extirpation value.



As with T_{DO3}, chl-*a* was evaluated to determine how well this measure predicts the presence of coldwater fishes using ROC curves and AUC scores. For the three coldwater fish species, the discrimination ability of models to predict species occurrence based on chl-*a* ranged from poor to outstanding (Figure 15). The Lake Trout model performed best with an AUC value of 0.9040 indicating that most lakes in the dataset with chl-*a* below 3 µg/L support Lake Trout. Chlorophyll-*a* was less predictive for Lake Whitefish and Cisco (Figure 15). There were a relatively high number of lakes with low chl-*a* concentrations that did not support these fish species (Figure 13; Table 11) which is similar to the pattern observed with T_{DO3} (see Table 10). As with T_{DO3}, the exact lake characteristics that make many of the lakes with good chl-*a* unsuitable for Lake Whitefish or Cisco could not be determined here, but it may be due to local biogeography or other lake-specific habitat characteristic that make these lakes unsuitable for these fish species. However, compared to T_{DO3}, chl-*a* performed poorer in predicting the presence or absence of all three fish species. The lower predictive ability of chl-*a* compared to T_{DO3} may have been related to T_{DO3} being a more proximate measure of coldwater habitat in lakes. In

addition, oxythermal habitat accounts for both oxygen and temperature conditions, whereas chl-*a* is more closely linked to the hypolimnetic oxygen component of coldwater fish habitat. Although there is a higher false positive error rates (i.e., lakes with low chl-*a* which do not support coldwater fishes; Table 11, Figure 13) for lakes with suitable chl-a conditions, it is apparent that these fish species are limited to lakes with lower productivity. These analyses support the draft chl-*a* thresholds and indicate that at these concentrations, false negative rates (i.e., predicting that a lake does not support coldwater fish species when in fact it does) are acceptable (~1-18%; Table 11).

Figure 15. Receiver operating characteristic (ROC) curves (upper row) and cut-off plots (bottom row) using chlorophyll-*a* as a predictor of species occurrence for A) Cisco (AUC = 0.6436), B) Lake Whitefish (AUC = 0.7489), and C) Lake Trout (AUC = 0.9135). Data were not censored for lakes with high colored dissolved organic matter (CDOM). For receiver operating characteristic curves, specificity refers to the true negativity rate and sensitivity refers to the true positivity rate. For error rate plots, solid lines are false negatives and dashed lines are false positives.

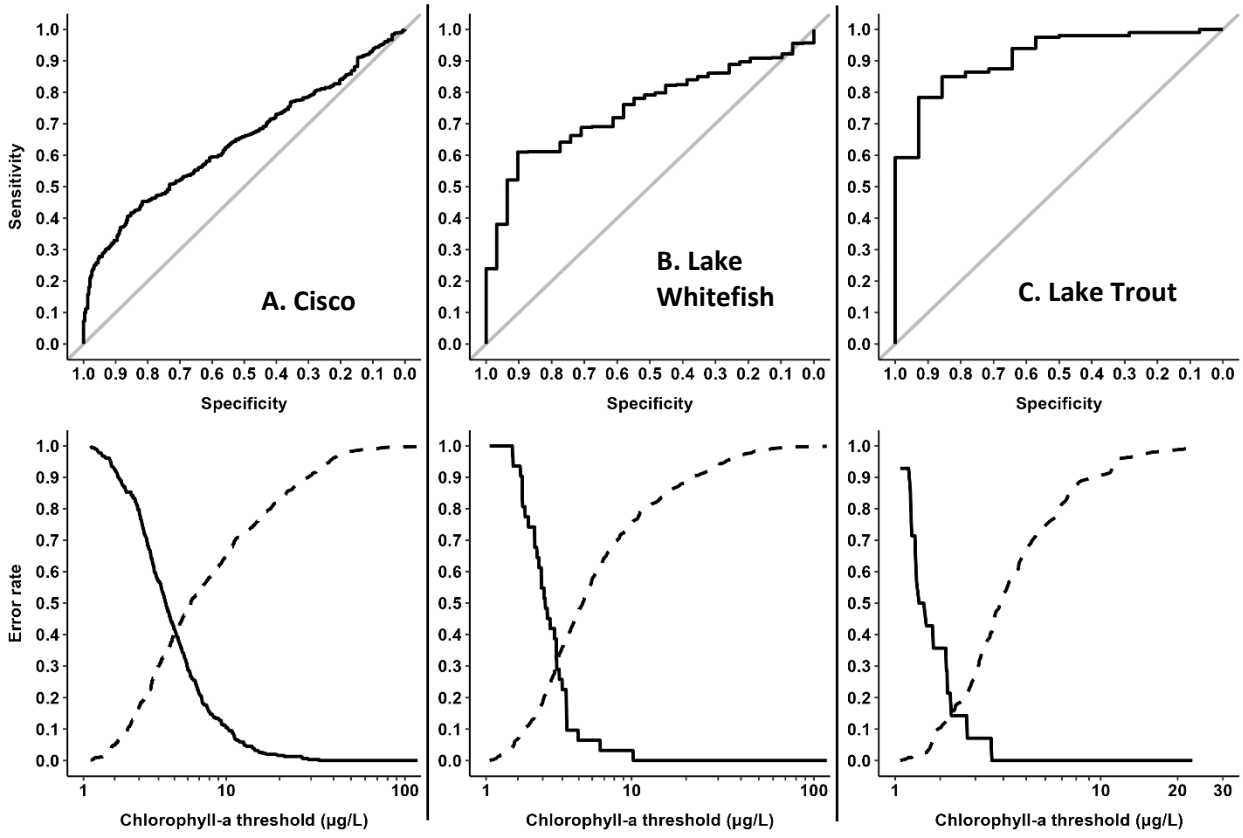
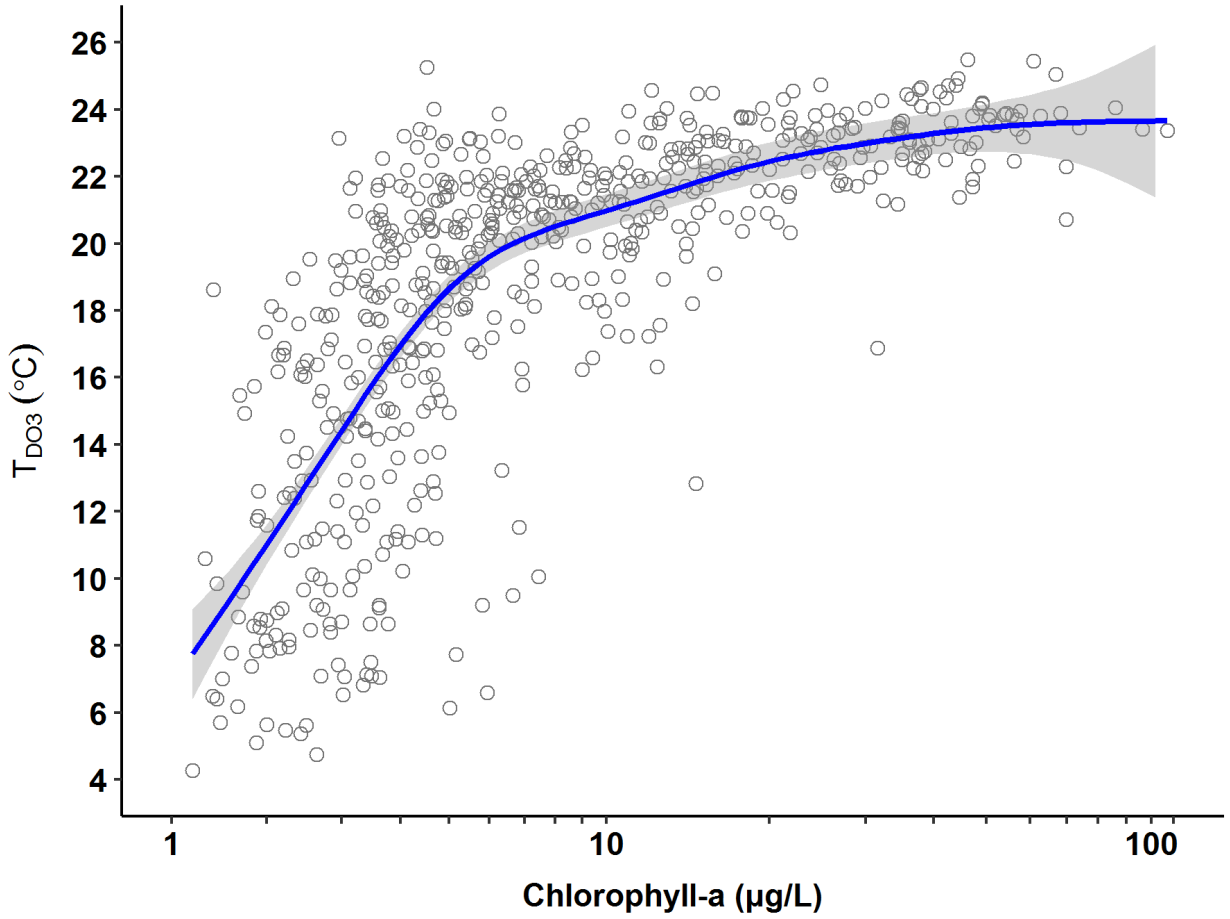


Table 11. Confusion matrices for predicting coldwater fish presence based on chlorophyll-*a* 95th percentile extirpation thresholds determined from abundance weighted cumulative distributions. Percentages are the proportion of lakes where the presence or absence of coldwater fishes was correctly or incorrectly predicted based on the draft standards. Blue cells are correct predictions and orange cells are incorrect predictions.

	Confusion matrix	
Cisco	**Chlorophyll-*a* exceeds**	**Chlorophyll -*a* meets**
Fish absent	141 (18%)	351 (44%)
Fish present	18 (2%)	288 (36%)
Lake Whitefish	**Chlorophyll-*a* exceeds**	**Chlorophyll-*a* meets**
Fish absent	386 (50%)	358 (46%)
Fish present	2 (0%)	29 (4%)
Lake Trout	**Chlorophyll-*a* exceeds**	**Chlorophyll-*a* meets**
Fish absent	146 (69%)	53 (25%)
Fish present	1 (0%)	13 (6%)

Protective thresholds for chl-*a* were not modeled directly from T_{DO3} because there are several lake-specific factors that can affect the relationship between these parameters. In dimictic lakes, there is an asymptotic relationship between chl-*a* and T_{DO3} with high variability in T_{DO3} at chl-*a* concentrations below ~6 µg/L (Figure 16). Above this threshold, T_{DO3} tends to be high although there is also considerable variability in this relationship. Variability in the relationship between chl-*a* and T_{DO3} is caused by several known lake-specific attributes which mitigate the effects of lake productivity on oxythermal habitat (EPA 2021). For example, EPA's deepwater hypoxia criteria models include the following lake-specific attributes to determine protective concentrations of chl-*a*: depth below thermocline, dissolved organic carbon (DOC), geographic location, and elevation (EPA 2021). Lower air temperatures for higher latitude and elevation lakes reduce water temperature and increase dissolved oxygen saturation which mitigates the effects of dissolved oxygen depletion caused by increased lake productivity. Deeper lakes will have a larger volume of oxygenated water following summer lake stratification which moderates the influence of dissolved oxygen depletion caused by increased oxygen demand in sediments and the hypolimnion (Müller et al. 2012, EPA 2021). Inputs of allochthonous organic matter can also increase lake productivity and oxygen depletion (Kritzberg et al. 2004, Pace et al. 2004) and DOC can be used as an indicator of this effect (Hanson et al. 2003, EPA 2021). The draft criteria provide a baseline of protective chl-*a* thresholds, but due to lake-specific characteristics, these criteria may need to be modified for individual lakes to ensure protection of these habitats.

Figure 16. Relationship between average chlorophyll-*a* and T_{DO3} based on dimictic lakes (geometry ratio < 4) with at least 2 years of chlorophyll-*a* data and 3 years of T_{DO3} data (1990-2020). Description of plot: fit is a generalized additive model (GAM) logistic regression (bs = "tp", k =10); shaded area: 90% confidence interval.



c. Total phosphorus and Secchi depth thresholds

Minnesota's current eutrophication standards for lakes include TP, chl-*a*, and Secchi depth (Heiskary and Wilson 2005; Minn. R. 7050.0222). These standards require an exceedance of both the nutrient (i.e., TP) and a response parameter (i.e., chl-*a* or Secchi depth). Of these three measures, chl-*a* provides the most proximate measure of lake productivity and whether beneficial uses are protected. Secchi depth also provides a reasonable estimate of lake productivity when water transparency is not affected by other factors such as colored dissolved organic matter (CDOM) and suspended sediment. Coupling TP and chl-*a* is useful in assessments because it can be used to diagnose atypical lakes and it ensures that the nutrient-response linkage matches that of the lakes used to develop the standards. Total phosphorus criteria are important because they serve as the basis for most management efforts for these waters including permitting, TMDLs, WRAPS, and protection plans. Ryan and Marshall (1994) identified all three of these water quality parameters as useful for predicting hypolimnetic oxygen depletion and to determine if habitat is suitable for Lake Trout. It is reasonable to include all three eutrophication measures as part of standards to protect coldwater fishes.

Statewide datasets were used to develop quantile regression models between TP and chl-*a* and chl-*a* and Secchi depth. Statewide average water quality values for lakes (1990-2020) were included. Due to the effect of the CDOM on Secchi depth, lakes with color >25 platinum-cobalt units (PCU) or absorptivity at 440 nm (a_{440}) >1.4 m^{-1} were censored from the chl-*a*-Secchi depth dataset. A 90th percentile quantile

regression was used for the TP and chl-*a* model (Figure 17) and the 10th percentile for the chl-*a* and Secchi depth model (Figure 18). The use of a 90th percentile model results in a high likelihood that if TP criteria are attained, the chl-*a* criteria will also be attained. The 10th percentile model for Secchi depth was used to reduce false positive errors in assessments. This is important because Secchi depth is used in these standards as a surrogate for chl-*a* in assessments. For each coldwater fish species, the chl-*a* thresholds (i.e., XC_{95} values) were used to interpolate values of TP and Secchi depth (Table 12).

Figure 17. Quantile regression fits for total phosphorus and chlorophyll-*a* used to model total phosphorus from chlorophyll-*a* thresholds for the protection of coldwater fishes. Points are summer average values for lakes (1990-2020). Lakes with color >25 PCU or a_{440} >1.4 m^{-1} were censored from the dataset. Grey lines: 90th or 10th percentile quantile regression fit (degree = 5, df = 6); dashed red lines: interpolations of total phosphorus from chlorophyll-*a* thresholds.

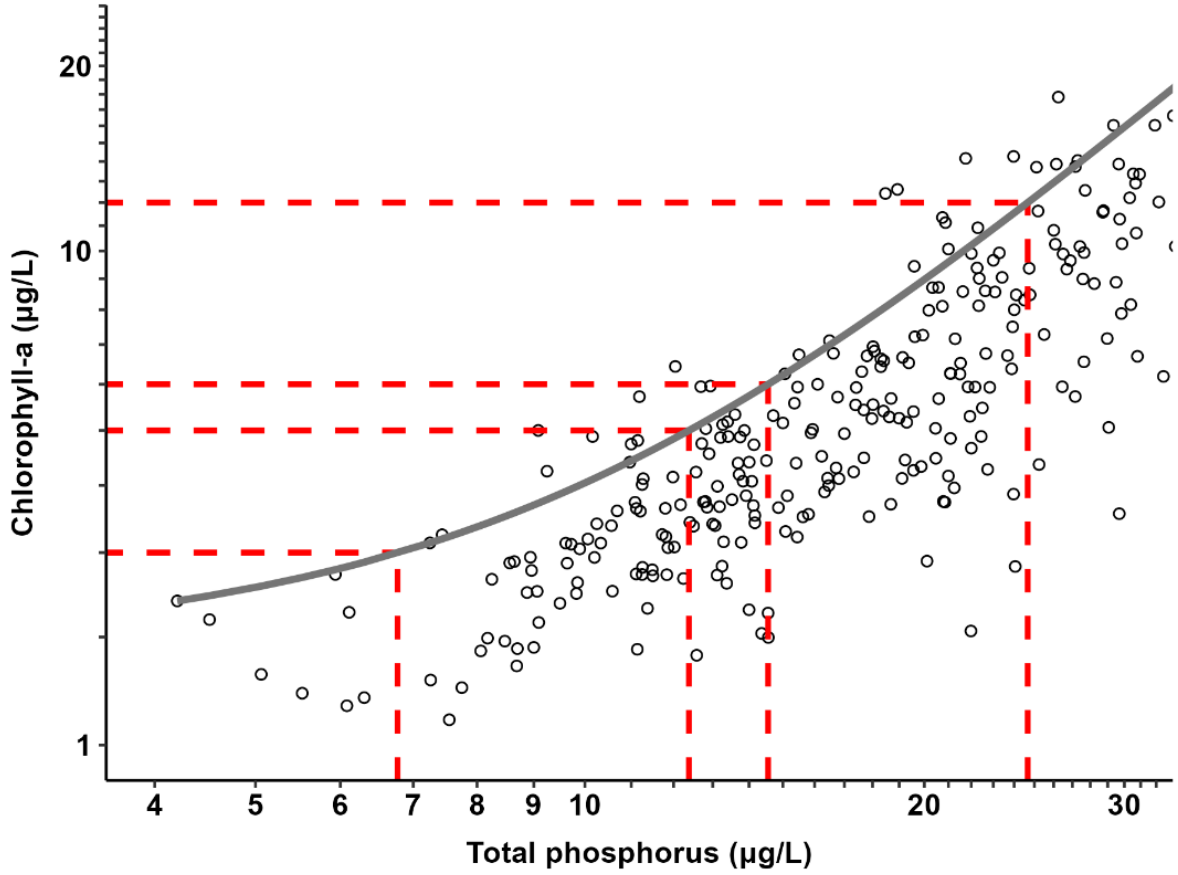


Figure 18. Quantile regression fits for chlorophyll-*a* and Secchi depth used to model Secchi depth from chlorophyll-*a* thresholds for the protection of coldwater fishes. Points are summer average values for lakes (1990-2020). Lakes with color >25 PCU or a_{440} >1.4 m^{-1} were censored from the dataset. Grey lines: 90th or 10th percentile quantile regression fit (degree = 7, df = 12); dashed red lines: interpolations of Secchi depth from chlorophyll-*a* thresholds.

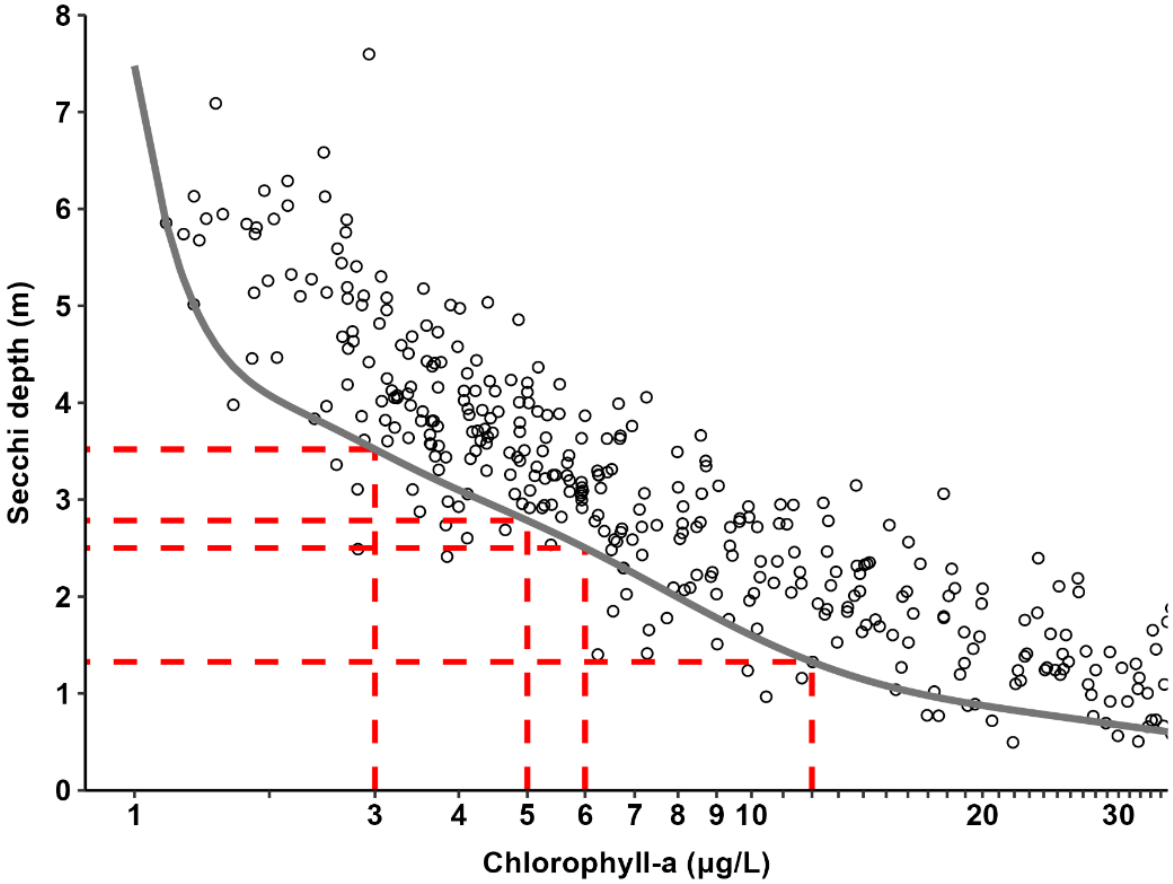


Table 12. Total phosphorus and Secchi depth thresholds interpolated from chlorophyll-*a* thresholds for Lake Trout, Lake Whitefish, Cisco, and stream trout (see Figures 17 and 18).

Species	Total phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi depth (m)
Lake Trout	7	3	3.5
Lake Whitefish	12	5	2.8
Cisco*	25	12	1.3
Stream trout	15	6	2.5

** The lake eutrophication criteria for Cisco lakes are less protective than the existing northern cool/warm water lake standards. As a result, the cool/warm water standards would be applicable to these lakes to protect the most sensitive endpoint.*

The TP criteria for Lake Trout and stream trout lakes are more stringent than current values because the current standards are based on a least squares regression model (Heiskary and Wilson 2005). The existing model reasonably predicts the TP-chl-*a* relationship for Minnesota lakes; however, there is a higher likelihood of false negatives, particularly for lakes near thresholds. Such lakes often fall into an "inconclusive" assessment category because TP is not exceeded, but chl-*a* is high. Since chl-*a* is a more direct measure of productivity than TP and some lakes are more productive at lower nutrient levels, it is reasonable to establish criteria that will acknowledge these lake attributes. The updated models result in more stringent criteria, but this will reduce false negative errors.

The Secchi depth criteria for Lake Trout and stream trout lakes are less stringent compared to current values. As with TP this is due to differences between the current least squares chl-*a*-Secchi depth model (Heiskary and Wilson 2005) and the quantile regression model provided in this study (Figure 18). Assessments should ideally be based on chl-*a* and TP when these data are available because chl-*a* provides a more proximate measure of lake productivity. Secchi depth is also a good predictor of lake productivity, but it may be affected by other factors that can introduce error into assessments. As a result, the 10th percentile was used to minimize these errors while still retaining the information Secchi depth can provide to an assessment, even when chl-*a* data are not available. In addition, assessments relying on Secchi depth will need to account for CDOM and suspended sediment as part of assessments to reduce false positive errors (see Implementation of coldwater lake fish standards).

There are currently no TP or Secchi depth standards specifically associated with the protection of Cisco and Lake Whitefish in Minnesota, but the draft criteria in this report are consistent with the relative sensitivity of Minnesota coldwater fishes. Based on these new standards, Lake Whitefish habitats are not sufficiently protected by any existing cool/warm water lake standards (Class 2B/2Bd). However, the protective levels of the current cool/warm water lake eutrophication standards are mixed for Cisco. Cisco lakes in the central nutrient region are not sufficiently protected by current standards. In contrast, the draft TP, chl-*a*, and Secchi depth thresholds for Cisco are less stringent than the cool/warm water standards for northern dimictic lakes. This means that lake eutrophication standards in the northern region are currently sufficient to protect Cisco lakes. As a result, the cool/warm water standards for dimictic lakes are more stringent and should continue to apply to these northern coldwater lakes[10].

iv. Draft coldwater habitat standards

A framework of WQS for the protection of coldwater lake habitats in Minnesota are provided by the current research. This framework consists of standards for oxythermal habitat and eutrophication for three fish species and a species group (Table 13). This includes creating two new lake types for Lake Whitefish and Cisco and the addition of a new parameter. These standards would only apply to lakes once they are designated as coldwater, and the species protected are defined in rule. For lakes supporting multiple coldwater fish species, the standards for the most sensitive will be used for assessment. A list of dimictic lakes supporting or managed for these coldwater fishes is provided in Appendix C.

Table 13. Draft oxythermal habitat (T_{DO3}), total phosphorus, chlorophyll-*a*, and Secchi depth thresholds for Lake Trout, Lake Whitefish, Cisco, and stream trout habitats (* indicates a threshold which is unchanged from the current standard).

Species	T_{DO3} (°C)	Total phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi depth (m)
Lake Trout	8.8	7	3*	3.5
Lake Whitefish	17.2	12	5	2.8
Cisco	21.2	25	12	1.3
Stream trout	-	15	6*	2.5

[10] Although these lakes are referred to as coldwater habitats, they support both coldwater and cool/warm water habitats. In many cases, these lakes can be referred to as two-story fisheries because both coexist in these lakes. As a result, the more sensitive use needs to be protected (i.e., northern region cool/warm water habitat) by the appropriate standards.

Oxythermal habitat is not currently implemented as a water quality standard in Minnesota. The current dissolved oxygen standard which applies to coldwater lakes is 7 mg/L, but this standard does not specify oxygen levels for the hypolimnion or metalimnion which are critical habitats for coldwater fishes in the summer in dimictic lakes. A lake may meet this standard in the epilimnion but fail to protect coldwater fish inhabiting the hypolimnion or metalimnion during summer stratification. The adoption of an oxythermal standard for the protection of coldwater fishes will improve management of these habitats by providing a direct measure of suitable habitat for these species.

The draft T_{DO3} standards do not necessarily reflect optimal conditions for these fish species, but rather are minimal conditions for their protection. As a result, the draft thresholds do not align exactly with reported optima and may more closely match lethal or avoidance levels for oxygen and temperature (Tables 5, 7, and 8). To maintain the health and viability of some populations of coldwater fishes in Minnesota lakes it will also be necessary to protect some lakes with better water quality than the draft standards. Such conditions should be considered as part of other regulations and programs such as antidegradation (see Minn. R. 7050.0250 through 7050.0335) and the protection of Cisco refuge lakes (Fang et al. 2012, Jiang and Fang 2016).

Although not providing a direct measurement of habitat, traditional lake eutrophication standards are also reasonable and effective for determining if coldwater habitats are protected (Ryan and Marshall 1994, Jacobson et al. 2010). The draft lake eutrophication standards to protect coldwater habitat include criteria for TP, chl-*a*, and Secchi depth. Although not as proximate a measure of coldwater habitat, these standards are largely equivalent to the draft oxythermal standards. As such, lake eutrophication and oxythermal standards can be used separately or in conjunction to ensure the protection of these habitats.

Comparison with other water quality programs

The importance of protecting coldwater fishes has been recognized in other water quality programs in the United States. State water quality programs with similar habitats and standards for the protection of coldwater fishes include Michigan and Wisconsin. In addition, the EPA has recently published lake eutrophication criteria which include criteria for deepwater hypoxia. A summary of these standards with a comparison to Minnesota's draft standards follows.

i. Michigan

In Michigan, coldwater fishery uses include lakes supporting trout, Lake Whitefish, and Cisco and there are dissolved oxygen standards for the protection of these fishes (State of Michigan 2006; R 323.1065 Dissolved oxygen; inland lakes). These standards include a minimum dissolved oxygen concentration (i.e., 7 mg/L) for coldwater habitats and specifies where this criterion needs to be met in a lake profile. Although 7 mg/L is applied to all coldwater lakes, the portion of the profile which must meet this criterion depends on the lake. Lakes are divided into three groups based on their capability to meet 7 mg/L in different portions of the water column including: 1) throughout the entire lake water column, 2) in the upper half of the hypolimnion (and thermocline and epilimnion), and 3) in the upper half of the thermocline (and epilimnion). The 7 mg/L criterion is similar to Minnesota's dissolved oxygen standard for coldwater lakes; however, Minnesota does not currently specify where in a lake this standard applies. As a result, Minnesota's current dissolved oxygen standard for coldwater lakes cannot be effectively and appropriately implemented to protect coldwater fishes.

ii. Wisconsin

Wisconsin's standards are based on the maintenance of a 1 m layer of water which meets species-specific oxythermal criteria (Lyons et al. 2018). For all three species (i.e., Cisco, Lake Whitefish, and Lake Trout), the same dissolved oxygen target of 6 mg/L is used, but temperature maximums differ between species. Specifically, Wisconsin requires a 1 m layer with dissolved oxygen ≥ 6 mg/L and temperature ≤ 22.8 °C for Cisco, ≤ 19 °C for Lake Whitefish, and ≤ 14 °C for Lake Trout. Based on logistic regression models of the probability of Minnesota lakes supporting Cisco (Figure 19A), a T_{DO3} of 21.2 °C has a similar probability (36%) of supporting Cisco compared to Wisconsin's standard for Cisco (30%). For Lake Whitefish (Figure 19B), a T_{DO3} of 17.2 °C has a similar probability (6%) of supporting Lake Whitefish compared to Wisconsin's standard (8%). At a T_{DO3} of 8.8 °C, 15% of lakes are predicted to support Lake Trout compared to 6% of lakes that meet Wisconsin's oxythermal habitat standard for Lake Trout (Figure 19C). We also directly compared Minnesota's draft standards to Wisconsin's standards using GAM models. Using this approach, we can determine if the different endpoints result in similar assessment outcomes. Interpolating Wisconsin's oxythermal habitat standard from a T_{DO3} of 21.2 °C results in a 1.3 m thick layer that meets Wisconsin's Cisco standard (Figure 20A). This result indicates that lakes meeting a T_{DO3} of 21.2 °C will on average meet or exceed Wisconsin's standards. A T_{DO3} of 17.2 °C is equivalent to a 0.0 m[11] layer that meets Wisconsin's Lake Whitefish standard (Figure 20B). For Lake Trout, a T_{DO3} of 8.8 °C is equivalent to a 1.7 m thick layer that meets Wisconsin's Lake Trout standard (Figure 20C). This indicates that Minnesota's standards are at least as stringent as Wisconsin's standards for Cisco and Lake Trout and less stringent than Wisconsin's Lake Whitefish standard. However, the outcomes of assessments based on these two sets of standards overall produces similar assessment outcomes (Figure 20 – confusion matrices). Based on this analysis, for the three fish species there is agreement in the oxythermal habitat status for 85-97% of lakes.

The comparability of these standards reflects the flexibility of oxythermal endpoints and how using different endpoints still results in similar protections. Oxythermal layers (e.g., 1 m of thickness where temperature is <22.8 °C and dissolved oxygen >6 mg/L) are correlated with oxythermal measures such as T_{DO3} and can be scaled to measure suitable coldwater habitat. These different oxythermal measures essentially measure the same conditions and by modifying the temperature target, each can be scaled to specific coldwater fish species. It is important not to focus too specifically on individual dissolved oxygen and temperature targets because these conditions are dynamic (e.g., Jacobson et al. 2008). For example, a layer of water with a dissolved oxygen of 2 mg/L and a temperature 21 °C may be survivable for Cisco, but so is a layer with a dissolved oxygen of 5 mg/L and a of temperature 25 °C. Therefore, focusing on the need for a lake to meet specific dissolved oxygen and temperature requirements based on laboratory studies may not address the variability of suitable coldwater fish habitat. However, fixed measures of oxythermal habitat can be used to predict the condition of coldwater habitat in lake for assessment and management purposes, but they should not be treated as optimal or lethal oxythermal thresholds for these species. As a result of the history of using T_{DO3} in Minnesota and its use to effectively identify coldwater fish habitat (e.g., Jacobson et al. 2010), this research is focused on this oxythermal measure. Although T_{DO3} is the primary endpoint used for developing coldwater fish thresholds, comparative analyses with other oxythermal measures are provided in this document to ensure that the use of T_{DO3} will not result in insufficient protection for these fishes or in assessment errors.

[11] A layer thickness of 0.0 m is equivalent to a T_{DO6} of 19 °C.

Figure 19. Comparison of probability of occurrence for A) Cisco, B) Lake Whitefish, and C) Lake Trout as a function of Wisconsin's draft oxythermal standards (left column) and T_{DO3} (right column). Description of figures: fits are generalized additive model (GAM) logistic regressions (bs = "tp", method = "REML", k = 4 [Cisco layer, Lake Whitefish layer], 7 [Lake Trout T_{DO3}], 10 [Cisco T_{DO3}, Lake Whitefish T_{DO3}, Lake Trout layer]); shaded areas = 90% confidence intervals.

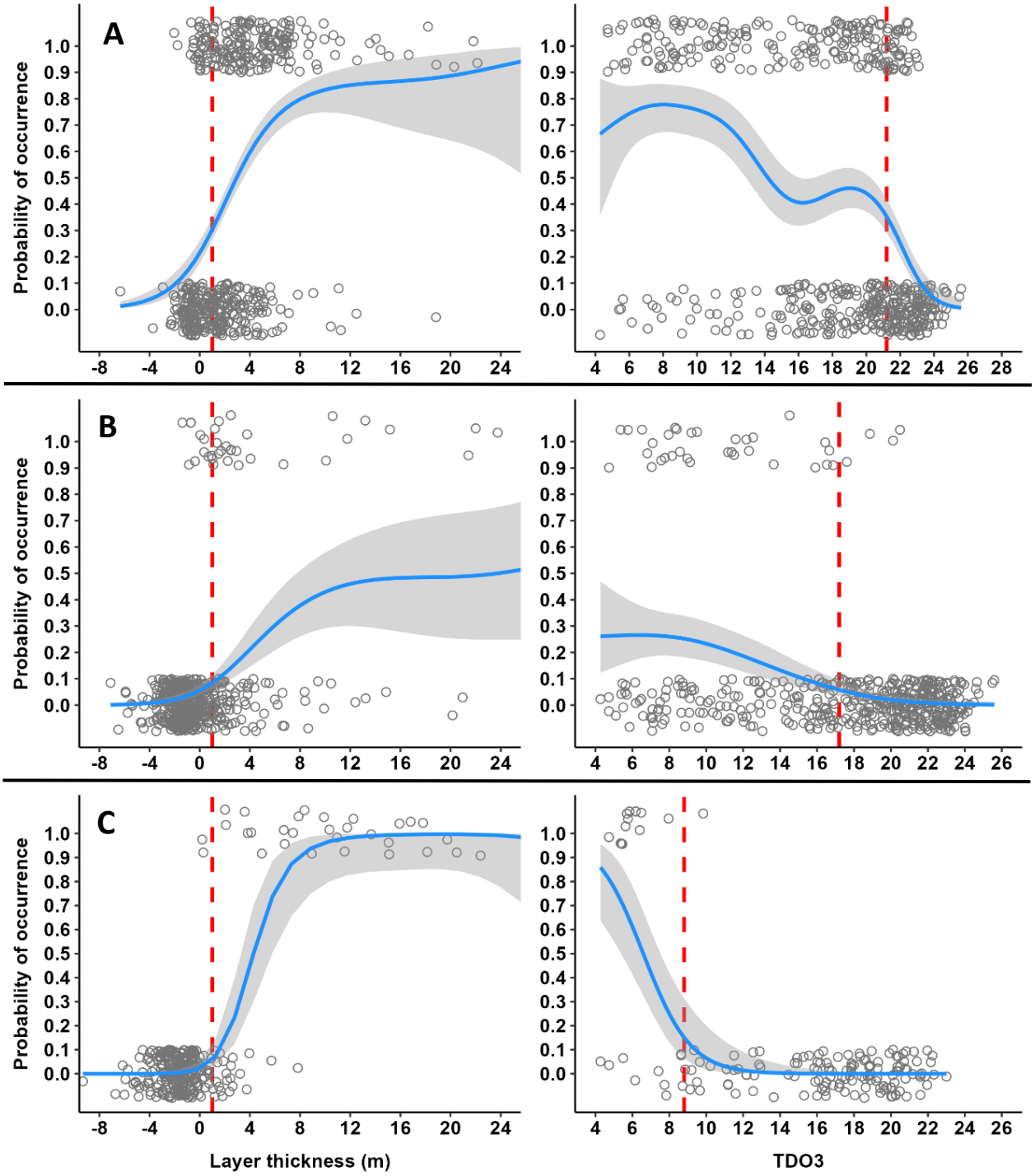
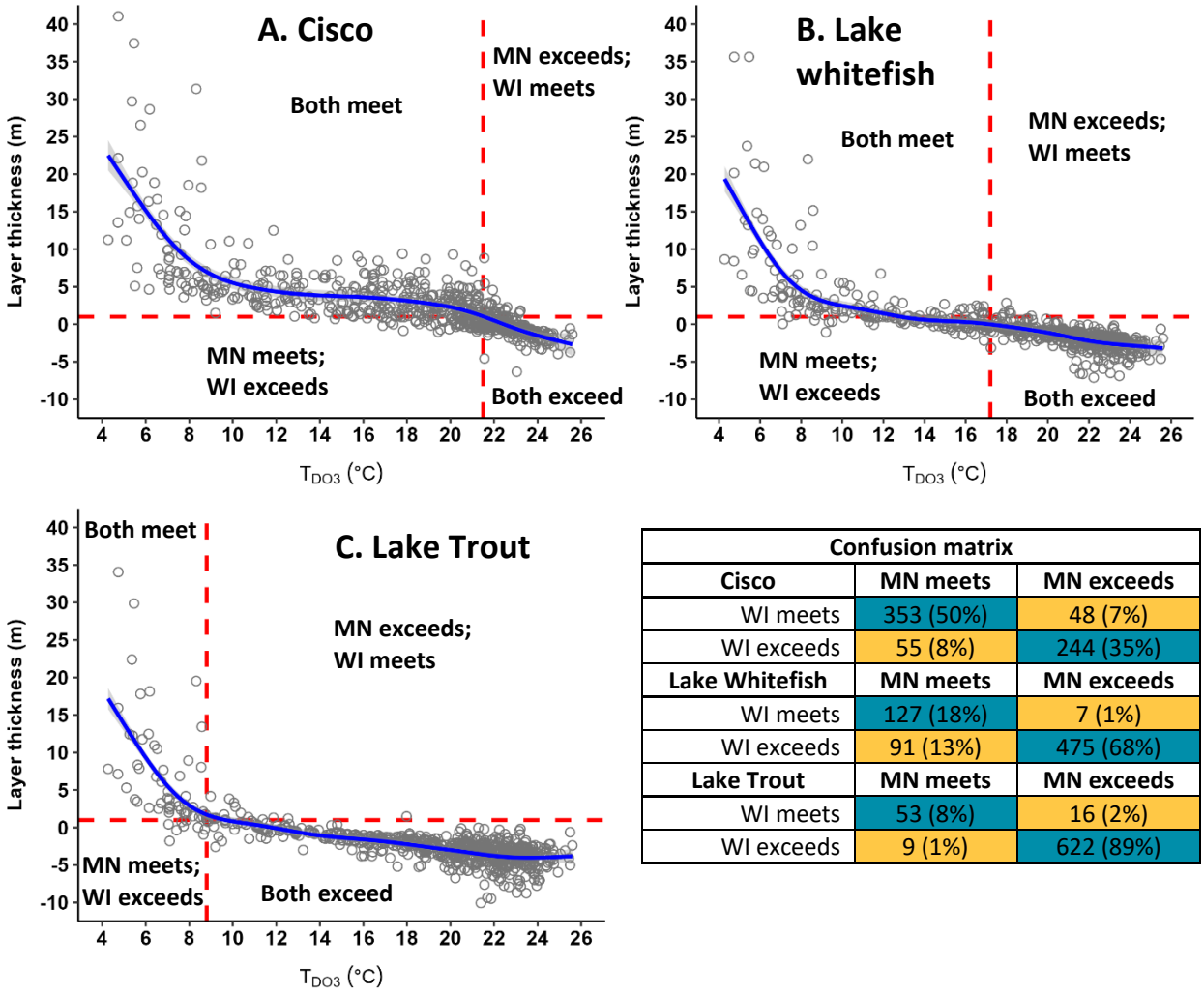


Figure 20. Comparison of T_{DO3} with Wisconsin's oxythermal measures: A) Cisco B) Lake Whitefish, and C) Lake Trout and confusion matrix. Datasets consist of lakes with at least 3 years of oxythermal data. Description of figures: fits are generalized additive model (GAM) logistic regressions (bs = "tp", method = "REML", k =10); shaded areas = 90% confidence intervals; red, dashed vertical line = Minnesota's draft T_{DO3} threshold; red, dashed horizontal line = Wisconsin's criteria (1 m layer thickness). For the confusion matrix, blue cells indicate that both standards resulted in the same outcome and orange cells indicate different outcomes between Minnesota and Wisconsin standards.



Confusion matrix		
Cisco	**MN meets**	**MN exceeds**
WI meets	353 (50%)	48 (7%)
WI exceeds	55 (8%)	244 (35%)
Lake Whitefish	**MN meets**	**MN exceeds**
WI meets	127 (18%)	7 (1%)
WI exceeds	91 (13%)	475 (68%)
Lake Trout	**MN meets**	**MN exceeds**
WI meets	53 (8%)	16 (2%)
WI exceeds	9 (1%)	622 (89%)

iii. United States Environmental Protection Agency

The EPA has developed recommended deepwater hypoxia criteria for cold and cool water fishes (EPA 2021). EPA's draft deepwater hypoxia criteria are based on the determination of chl-*a* concentrations required to maintain a layer of sufficiently oxygenated water meeting temperatures critical for the protection of cold and cool water organisms. This approach differs from those of Minnesota and Wisconsin in that it does not directly develop oxythermal standards from fisheries data. Rather it relies on users to select protective oxythermal criteria parameters including layer thickness, critical temperature, dissolved oxygen level, and certainty level[12]. These inputs, along with lake-specific characteristics (i.e., depth below thermocline, geographic location, and elevation), are used to model

[12] The credible interval in Bayesian statistics is similar to confidence limits in frequentist statistics.

chl-*a* concentrations needed to meet the selected oxythermal habitat target for a lake. The determination of criteria in EPA's deep water hypoxia framework are site specific and differ from Minnesota's draft standards which are species specific. The draft Minnesota criteria and EPA's draft standards accomplish similar overall objectives, but the lack of specific oxythermal endpoints and the determination of site-specific criteria in EPA's models make direct comparisons difficult. However, we can make some tentative comparisons using data from a subset of Minnesota lakes and calculating lake-specific criteria for these lake with EPA's interactive tool for deepwater hypoxia (https://nsteps.epa.gov/apps/chl-hypoxia/). The EPA's tool requires protective oxythermal attributes to be selected by the user including critical temperature, refugia thickness, dissolved oxygen threshold, and certainty level. The draft Minnesota standard parameters could not be exactly replicated using EPA's tool, so for comparison parameters as close to Minnesota's draft framework were input into the model. As such, this exercise only compares chl-*a* criteria between the two approaches and does not assess if oxythermal criteria would differ.

To approximately match draft oxythermal thresholds, we selected the minimum refugia thickness allowed by the model tool (30 cm). The critical temperature and dissolved oxygen thresholds selected differed depending on the most sensitive coldwater fish species present. These were modified to approximate the T_{DO3} thresholds as much as possible which required adjustments to both the critical temperature and dissolved oxygen threshold. The selected thresholds for temperature were 14 °C for Lake Trout, 17 °C for Lake Whitefish, and 21 °C for Cisco and thresholds for dissolved oxygen were 6 mg/L for Lake Trout, 4 mg/L for Lake Whitefish, and 4 mg/L for Cisco (Table 14). For Lake Trout, the minimum critical temperature (13-14 °C) was selected as the lowest valued that did not produce a model error. The dissolved oxygen threshold could not be set at 3 mg/L, so the minimum value of 4 mg/L was selected. A certainty level of 90% was selected for all lakes. Chl-*a* criteria based on the EPA deepwater hypoxia models were calculated for five lakes including two Lake Trout lakes (Trout, Greenwood), one Lake Whitefish lake (Ten Mile), and two Cisco lakes (Carlos, Locator). These lakes were selected because they are draft coldwater lake use designations for these coldwater fish species (Appendix C) and because sufficient data to run the model was available. Lakes with at least two years of DOC data available were selected. In all five lakes, the deepwater hypoxia model resulted chl-*a* criteria (Table 15) which as or more restrictive (2.3-4.6 µg/L) than the draft Minnesota criteria (Table 15). Total phosphorus concentrations were also modeled from EPA target chl-*a* concentrations using EPA's interactive tool (https://tp-tn-chl-prod.app.cloud.gov/). The EPA's recommended nitrogen criteria tool was not reviewed here because development of nitrogen criteria was not considered for Minnesota lakes due to data limitations and the narrow scope of this project. In the two Lake Trout lakes and the Lake Whitefish lake, the draft Minnesota and the EPA chl-*a* criteria were similar. For the other two lakes (Cisco lakes), the EPA chl-*a* criteria were lower than Minnesota's draft criteria. However, based on the analyses in this report, Cisco are sustainable in lakes with chl-*a* considerably higher than these thresholds. The TP criteria derived from EPA's models had a similar pattern with comparable thresholds in the Lake Trout and Lake Whitefish lakes and more stringent thresholds in the Cisco lakes. An important note is that these five lakes do not represent a random sample of Minnesota coldwater lakes so limited conclusions can be drawn from this exercise; however, the draft criteria for Minnesota's coldwater lakes appear in general to be protective.

Table 14. Input values for EPA's deepwater hypoxia model (EPA 2021) used to model chlorophyll-*a* targets for a subset of Minnesota lakes. Chlorophyll-*a* model results were based on EPA's interactive tool (https://nsteps.epa.gov/apps/chl-hypoxia/; accessed on November 20, 2024) and are in Table 15. Abbreviations: WID = waterbody identification code; T = temperature; DO = dissolved oxygen; DOC = dissolved organic carbon; LAT = Lake Trout, LKW = Lake Whitefish, TLC = Cisco.

WID	Lake name (most sensitive species)	Longitude, Latitude	Elevation (m)	Area (km^2)	Critical T (°C)	DO threshold (mg/L)	DOC (mg/L)	Thermocline depth (m)
16-0049-00	Trout] (LAT)	-90.17, 47.87	500	1	14*	6	4.0	12
16-0077-00	Greenwood (LAT)	-90.17, 48.00	550	8	13*	6	5.1	22
11-0413-00	Ten Mile (LKW)	-94.58, 46.97	400	20	17	4*	3.6	52
21-0057-00	Carlos (TLC)	-95.36, 45.97	400	11	21	4*	6.5	39
15-0010-00	Elk (TLC)	-95.22, 47.19	450	1	21	4*	7.9	25

** The minimum possible value allowable by the model was selected.*

Table 15. Input values (see also Table 14) and results of EPA's deepwater hypoxia (chl-*a*) and total phosphorus models (EPA 2021) for a subset of Minnesota lakes. Total phosphorus model results are based on EPA's interactive tool (https://tp-tn-chl-prod.app.cloud.gov/; accessed November 20, 2024) and used the Northern Lakes and Forest ecoregion and 90% certainty level. The chl-*a* targets were modeled using the inputs in Table 14 from the deepwater hypoxia model. Abbreviations: WID = waterbody identification code; DOC = dissolved organic carbon; Chl-*a* = chlorophyll-*a*, TP = total phosphorus, LAT = Lake Trout, LKW = Lake Whitefish, TLC = Cisco.

				EPA model results		Draft Minnesota standard	
WID	Lake name (most sensitive species)	DOC (mg/L)	Maximum depth (m)	Chl-*a* target (µg/L)[#]	TP criterion (µg/L)	Chl-*a* (µg/L)	TP (µg/L)
16-0049-00	Trout (LAT)	4.0	23	3.3	10	3	7
16-0077-00	Greenwood (LAT)	5.1	34	2.7	10	3	7
11-0413-00	Ten Mile (LWF)	3.6	63*	4.4	11	5	12
21-0057-00	Carlos (TLC)	6.5	50	4.6	12	12	25
15-0010-00	Elk (TLC)	7.9	28	2.3	8	12	25

** The maximum possible value (60 m) allowable by the model was selected.*

[#] *Only whole numbers could be input so chl-a targets were rounded to the nearest integer.*

Implementation of coldwater lake fish standards

The methods and requirements for performing assessments of coldwater lake habitats need to be described to ensure appropriate application of these standards and to minimize erroneous assessment decisions. Central to an assessment framework is where and how data need to be collected and what the minimum data requirements are for assessment. This includes considerations for lakes where monitored data are near thresholds. In addition, it is helpful to describe how to assess atypical situations where either the data collected are unusual or contradictory or for lakes that are unique. These aspects

of implementing an assessment framework for coldwater lake habitat are described in the following section.

i. Sampling location

Coldwater lake standards are focused on assessing the condition of coldwater habitat within a lake which may be suitable to support coldwater fish species. However, that habitat does not exist throughout a lake when it is stratified and is usually associated with the deepest areas of a lake. As a result, collection of temperature and oxygen profiles should be from the deepest area or basin of a lake where coldwater fishes are likely to reside during the summer. When possible, a single station from the deepest area of a lake should be used for assessments. In cases where multiple distinct basins are present in a lake and these basins differ in terms of depth and trophic state, measurements from multiple basins may be averaged. If these basins are highly distinct and water quality or fisheries management differs between these basins, it may be necessary to designate separate WIDs for each basin. However, if assessments ensure that lake profile data used for assessments are from the deepest area of the lake, the splitting of a lake into subbasins will often not be necessary. In addition, where possible it is preferable to assign similar management units to that of the MNDNR. In most cases, the MNDNR includes all basins of a lake as a single management unit even if there are multiple fish community types managed in different zones (e.g., two-story lakes or morphologically complex lakes where only some basins support coldwater fishes). The measurement of eutrophication parameters (i.e., TP, chl-*a*, and Secchi depth) are also usually collected from the deepest area, but sample location is not as important for these measures. However, in complex lakes with multiple distinct basins, eutrophication measures should be collected from the same basin as the lake profiles used for the assessment of T_{DO3}. The goal of water quality data collection for the assessment of coldwater habitats is to collect samples that accurately reflect the available and usable habitat which is needed to maintain populations of coldwater fishes in these lakes.

ii. Oxythermal habitat

Specific temporal data requirements will need to be met to assess T_{DO3} in coldwater lakes. At least one profile should be taken per summer for three years[13]. Sampling should be focused on the 30-d period of maximum oxythermal stress (i.e., July 26 through August 24); however, for data used for a determination of impairment, lake temperature and oxygen profiles may be collected at any time during the summer index period (June through September). Determination of full support requires these data to be collected during the period of maximum oxythermal stress (i.e., July 26 through August 24). Oxythermal data from outside the period of maximum oxythermal stress may be used as supporting information for determining support of these standards. Measurement of T_{DO3} should be collected at depth intervals of ≤1m at the depth where the 3 mg/L dissolved oxygen threshold is crossed. Greater depth intervals are acceptable above and below this threshold. Profiles collected using depth intervals >1m at the 3 mg/L dissolved oxygen threshold, may be used if a review of these data indicate that the profile is indicative of oxythermal conditions. For example, the profile may clearly demonstrate attainment or nonattainment of oxythermal thresholds. If such profiles are deemed to not be indicative of oxythermal conditions, they may be relegated to supporting information.

[13] In some cases, assessments using less than 3 years of data may be acceptable if there is high confidence in the available data. For example, it may be reasonable to assess cisco lakes in the BWCAW with 2 years of T_{DO3} measurements indicating very good oxythermal conditions. See the discussion below regarding confidence limits.

In most lake profiles, calculation of T_{DO3} will be a simple interpolation of the temperature at the depth where dissolved oxygen is 3 mg/L. However, in some profiles this is not possible because the dissolved oxygen profile never crosses this threshold, or the profile is more complex. For lake profiles where DO_{max} is less than 3 mg/L, T_{max} is used in place of T_{DO3}. When the opposite is true and a lake profile has a DO_{min} greater than 3 mg/L, T_{min} is used in place of T_{DO3}. In unusual cases where dissolved oxygen drops below 3mg/L but then increases above this dissolved oxygen threshold again at a deeper depth, the T_{DO3} from the deeper depth will be used.

If lake profiles have been sampled at multiple locations within a lake, the most appropriate sampling station (usually deepest part of the lake) will need to be identified (see previous section). It may be possible to use multiple stations from a lake if these areas or basins have been determined (e.g., using depth contours or a defined geospatial area) to be likely support summer refugia for these fishes. If T_{DO3} measurements from multiple stations are available on the same day, the lowest T_{DO3} value may also be used since this may represent the best coldwater habitat within a lake. If multiple T_{DO3} measurements are available from the same year, the highest value will be used in assessment as this reflects the greatest measured stress to which the fish were exposed. Assessments will consist of a comparison of average T_{DO3} from the most recent 10 years against the standards assigned to a lake based on the fish species protected in the lake. If oxythermal data from outside the period of oxythermal stress is present and exceeds the standard, these data can be included in the average or used as supplemental data. However, it should be determined if poor oxythermal conditions (i.e., high T_{DO3} values) are the result of atypical conditions (e.g., severe drought). In which case it may not be appropriate to include these data in the calculation of the average and they should be relegated to supplemental data. If data outside the oxythermal index period are included in the average, other data from the same year should not be included in the average. Inclusion of data exceeding the standards from outside the index period is useful and informative in assessments because if a lake is experiencing low oxythermal conditions outside the oxythermal index period, it is likely to exceed standards during the index period. This enables the inclusion of additional data that would otherwise be excluded and can provide additional insight into the severity of the WQS exceedance.

As more continuous monitoring of temperature and dissolved oxygen are available from lakes, these data may also be incorporated into assessments. In most cases, the probe intervals will be greater than 1 m and not suitable for determining T_{DO3}. However, these data may provide useful supplemental data such as determining if a discrete T_{DO3} measurement on a lake was collected on a day that was an outlier. If continuous temperature and dissolved oxygen data are collected at 1 m or less increments, these data may be suitable for assessments. These data could be used by determining the day with the highest T_{DO3} value during the period of deployment. In general, continuous monitoring data will also be valuable for documenting temperature and dissolved oxygen patterns in lakes and thereby improve implementation of T_{DO3} standards.

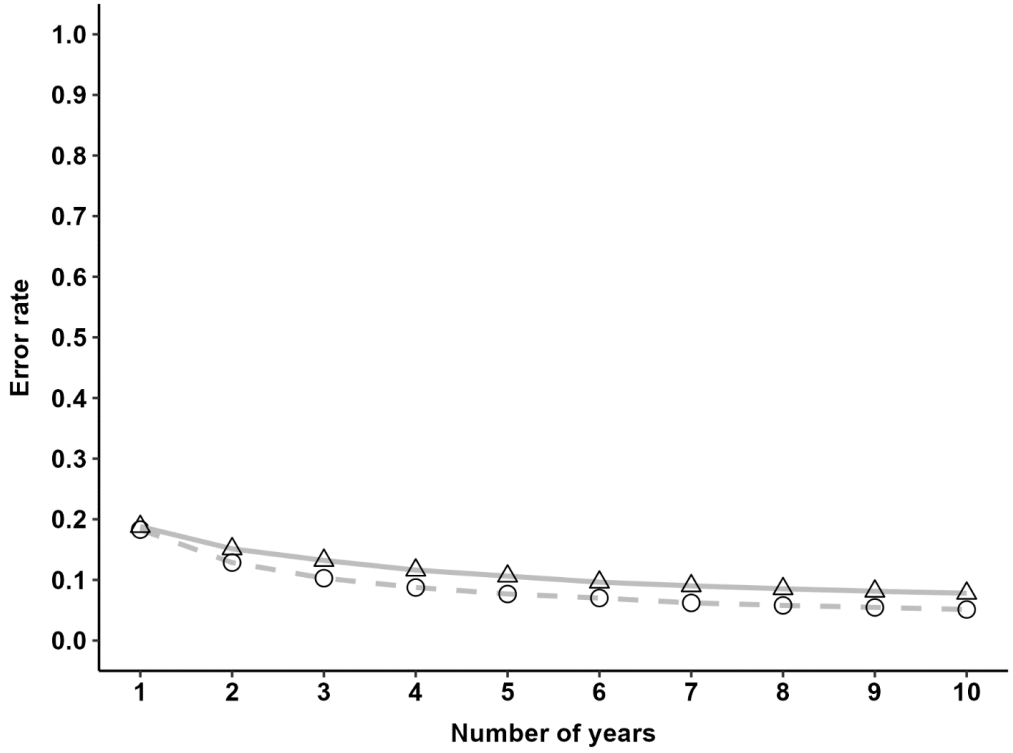
Beyond a straightforward assessment of average T_{DO3}, other data attributes can be considered to ensure appropriate assessment outcomes (i.e., avoiding false negatives or false positives). Sample size (i.e., number of years of T_{DO3} data available) impacts the parameter estimation. The effect of sample size on error rates was analyzed by bootstrapping (B = 1000) and estimating mean T_{DO3} at different sample sizes from dimictic lakes (geometry ratio < 4) with at least 10 years of data (n = 144). Error rates were estimated as the number of individual replicate assessments which differed from an assessment[14] based on the mean T_{DO3} of all 1000 replicate samples. To assess the confidence limits of a 3-year sample size,

[14] Assessments were based on the cisco T_{DO3} draft standard (T_{DO3} = 21.2 °C). Therefore, if the bootstrapped mean T_{DO3} indicated that a lake did not meet the cisco T_{DO3} draft standard, all replicate mean values that indicated attainment of this standard were considered errors.

3-year replicates were bootstrapped (*B* = 1000) from the same dataset of lakes with at least 10 years of data. For these lakes, 90% confidence limits were estimated from these bootstrapped samples by calculating 5th and 95th percentiles for each lake. The upper and lower confidence limits were estimated as the difference between the 5th and 95th percentiles and confidence limit widths were calculated as the difference between the 5th and 95th percentiles and the mean. The average of the upper and lower confidence limit widths was calculated and used to estimate variability in oxythermal habitat for each lake.

As sampling size increased, false positive and false negative errors decreased although there was no obvious breakpoint or lower asymptote for the sample sizes analyzed (Figure 21). A sample of three years was selected as a minimum dataset to reduce errors and maximize the number of lakes for which a sufficient dataset will be available. Although increased sample size reduces estimation error and is preferable when available, additional review of data and separate lines of evidence can be used in combination with T_{DO3} data to reduce assessment errors. It is important to note that these analyses used raw data which have not been scrutinized as in an assessment which likely increased estimated error rates. As a result, the absolute error rate values are likely to be lower as part of a fully implemented water quality assessment program.

Figure 21. Error rates (circles = false positives; triangles = false negatives) for different sample sizes estimated using bootstrapping (B = 1000). Dataset consisted of dimictic lakes with at least 10 years of data.



Confidence limits for estimating T_{DO3} from individual lakes will differ depending on available datasets, time of sampling during the index period, years sampled, and random sampling error. An analysis of confidence limits for individual lakes can be used to determine when additional scrutiny or sampling may be prudent to accurately estimate oxythermal conditions. The distribution of confidence limits for the 144 dimictic lakes with at least 10 years of oxythermal habitat data is provided in Figure 22. Most dimictic lakes (83%) had upper/lower confidence limits below 3 °C (Figure 22A). Review of individual T_{DO3} measurements can give insight into estimated average measurements. Large year-to-year variability in T_{DO3} may indicate a need for additional sampling and these data can be manually examined or assessed using bootstrapping. Specific considerations for individual measurements include reviewing weather

conditions (e.g., high temperatures, drought) during the time of sampling, the degree to which individual measurements exceed standards, proximity of average T_{DO3} to the standard, the estimated mean T_{DO3}, and contemporaneous fish surveys. Particularly high or low individual T_{DO3} measurements may be important for assessment decisions. For example, it may be appropriate to assess a lake near the standard as impaired if one or more of the years greatly exceeded the standard. In addition, review of weather conditions may provide insight into T_{DO3} measurements and could affect assessment decisions if a large proportion of measurements were collected during atypical years or periods. If all or most of the available data for a lake were collected during a warmer-than-average period, additional sampling may be recommended before making an assessment decision. The proximity of average T_{DO3} to the standard is important because assessment errors will increase as that gap narrows. For example, a lake with a mean T_{DO3} of 12 °C is unlikely to exceed the draft criterion for Cisco of 21.2 °C. The estimated T_{DO3} value may also be important because confidence limits vary as a function of T_{DO3} (Figure 22B; Table 16). We selected a subset of three lakes with at least 10 years of lake profile data and with different distributions of T_{DO3} measurements. These lakes included lakes with low, intermediate, and high T_{DO3} levels. Based on Figure 22B, lakes with low or high mean T_{DO3} values had narrower confidence limits (e.g., Figure 23A,C). Therefore, there is greater confidence in these estimates. Lakes with mid-range T_{DO3} values tended to have wider confidence limits (e.g., Figure 23B). It is not clear why this pattern occurs in these lakes, but it indicates that additional scrutiny may be needed for such lakes and for lakes that are near T_{DO3} criteria. For example, the current condition of coldwater fish populations may be used to inform assessments, as lakes with T_{DO3} values near the criterion but with a healthy population of coldwater fish species, indicate that standards are attained. In general, these confidence limits and other considerations provide guidelines for when additional review of individual T_{DO3} measurements or sampling should be recommended to minimize assessment error.

Figure 22. (A) Histogram of upper and lower confidence limits and (B) estimated confidence limits as a function of T_{DO3} for individual lakes. Confidence limits were estimated by bootstrapping (B = 1000) 3-year replicates. The dataset for both figures consisted of dimictic lakes with at least 10 years of data (n =144). Fits for (B) are generalized additive models (GAM; bs = "tp") including mean, 95th percentile, and 5th percentile.

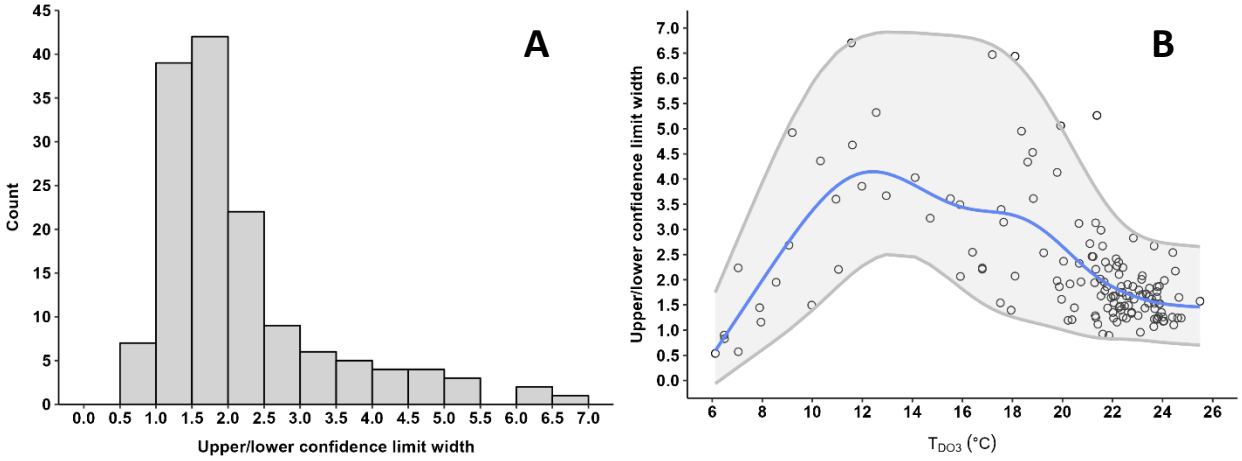
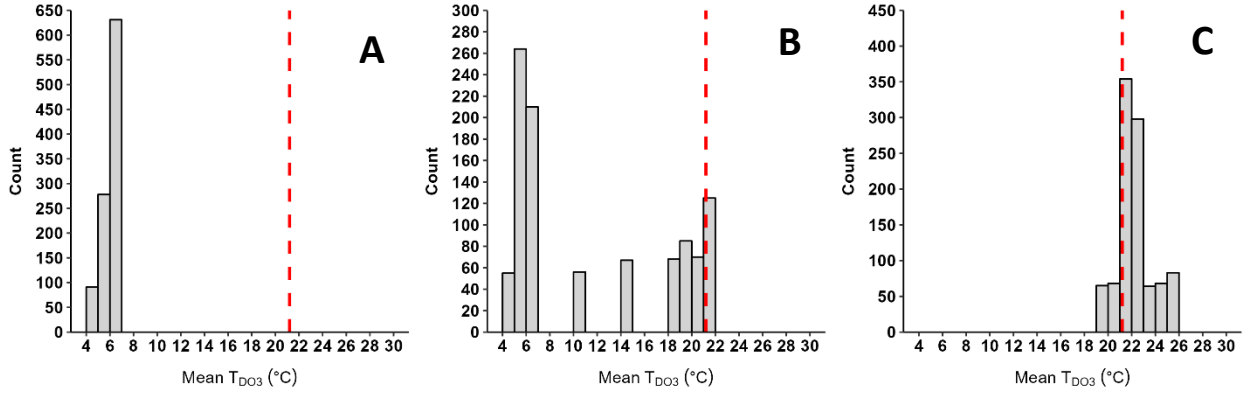


Table 16. Modeled confidence limits (C.L.) as a function of mean T_{DO3}. The values are derived from the analysis in Figure 22B. The mean confidence limits correspond to the blue line and the 95th percentile values correspond to the upper grey line in Figure 22B.

Mean T_{DO3}	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Mean C.L.	1.2	1.9	2.7	3.4	4.0	4.3	4.2	3.8	3.5	3.2	3.3	3.4	3.2	2.7	2.2	1.8	1.6	1.5
95th percentile C.L.	2.8	3.9	5.0	5.9	6.5	6.8	6.9	6.9	6.9	6.8	6.7	6.4	5.8	5.0	4.1	3.3	2.9	2.7

Figure 23. Histograms of mean T_{DO3} from bootstrapped samples (n = 3; *B* = 1000) for (A) Grindstone Lake (58-0123-00), (B) Cedar Lake (01-0209-00), and (C) Big Swan Lake (77-0023-00). Red dashed line = draft Cisco criterion.



iii. Total phosphorus, chlorophyll-a, and Secchi depth

Assessment of eutrophication parameters for coldwater lakes will follow existing lake eutrophication assessment guidance (MCPA 2024a). Sampling needs to occur during the summer index period (June through September) and samples should collected throughout this period. A minimum of two years of monitoring with at least four samples per year are required to perform an assessment. A determination of impairment is based on the exceedance of TP and one or both response parameters (chl-*a* or Secchi depth). All available data from the most recent ten years, assuming the 2-year minimum is met, is used for assessment and these data are averaged. If there is uneven sampling effort between years for a lake, data may need to be weighted by year to avoid bias. CDOM should be considered when Secchi depth is assessed as it can impact transparency (MPCA 2024b). Both color (PCU) or a_{440} can be used to determine if CDOM is negatively impacting Secchi depth and possibly invalidating this parameter as a measure of productivity. Lakes with color >73 PCU or a_{440} >4 m^{-1} should not be assessed using Secchi depth (Brezonik et al. 2019) and lakes with color >25 PCU or a_{440} >1.4 m^{-1} should be scrutinized to determine if an assessment is appropriate (MPCA 2024b). In many cases, it may be advisable to use only chl-*a* for assessment in lakes with elevated CDOM as Secchi depth measurements will not provide an accurate measure of lake productivity. Although it is not a widespread issue in coldwater lakes, suspended sediment may also need to be accounted for as part of Secchi depth assessments. Additional details regarding methods for the assessment of eutrophication in lakes can be found in MCPA (2024a).

iv. Multiple indicators

The draft coldwater habitat standards include multiple indicators for determining the attainment and protection of coldwater habitat goals. Eutrophication and oxythermal measures can measure similar impacts to coldwater fishes, but oxythermal measures may be a more comprehensive indicator. The oxythermal habitat standards incorporate both oxygen and temperature requirements for these sensitive fish. The eutrophication portion of this standard is largely a determinant of dissolved oxygen conditions although it will also be sensitive to other potential impacts such as food web alterations and harmful algal blooms. In many cases, these two indicators will agree, but in some lakes assessment outcomes may differ. Because there are multiple indicators and these indicators will conflict in some lakes, it is necessary to describe how these situations will be addressed in assessments. In these cases, a weight-of-evidence approach will need to be considered to minimize assessment error. This process is described below in detail and in a flowchart provided in Appendix A.

The oxythermal and eutrophication parameters, when both are available for a lake, are intended to be used together although they can be implemented independently. If a lake has only one of these indicators (i.e., T_{DO3} or TP and chl-*a*/Secchi depth), that is sufficient to perform an assessment. When both are available, these indicators can be used independently (i.e., determine a lake is impaired when one indicator demonstrates impairment, but the other does not). However, a more detailed review of the available data may reveal that one indicator is more appropriate. This may be due to one indicator consisting of a larger, more comprehensive dataset or it may be a better indicator for a specific lake. In cases where lakes have oxythermal habitat and eutrophication outcomes which disagree (assuming both have sufficient datasets for assessment), the size and robustness of each dataset should be considered. For example, if one indicator includes many more years of data or demonstrates lower variability in the estimation of parameter means, then it may be reasonable to use that parameter for assessment. In some cases, the use of eutrophication standards may not be appropriate due to impacts from zebra mussel infestations. These lakes may have lower mid-lake water column chl-*a* which does not accurately reflect the productivity of the system or the potential impacts to coldwater communities. This means that a decision of full support can be made even if one parameter exceeds that standard when the other parameter is determined to be a better, more accurate indicator of coldwater habitat. In cases where datasets for oxythermal habitat and eutrophication are similarly robust, more weight may be given to oxythermal habitat since it is a more proximate indicator of coldwater habitat. In addition, a recommendation to collect more data can be made when these results are deemed inconclusive. It may also be appropriate for some lakes to develop site-specific standard (SSS) to acknowledge a different relationship between oxythermal and eutrophication measures than that observed with the population of lakes used to develop these standards. Multiple indicators are useful for making use of available datasets, but when complementary data are available, these data should be scrutinized to determine how to implement an assessment such that an appropriate determination is made regarding the ability of a lake to support coldwater fishes.

v. Impaired waters and TMDLs

The inclusion of both T_{DO3} and chl-*a* in assessments provides information regarding stressors responsible for the loss or degradation of coldwater lake habitats. T_{DO3} provides a more direct measure of a lake's coldwater habitat conditions, but it is affected by both changes in temperature (e.g., climate change) and lake productivity (e.g., cultural eutrophication). Chl-*a* is largely affected by lake productivity although there are interactive effects between productivity and temperature. As a result, which criteria are exceeded (T_{DO3}, chl-*a*, or both) can be informative regarding stressors and the need to develop a TMDL (i.e., 303(d) listing category). The two most relevant categories for lakes not meeting coldwater habitat standards are initially Category 4C and Category 5 (Table 17). Category 4C lakes are those that are impaired, but do not require a TMDL because non-attainment is caused by a non-pollutant (e.g., flow alteration or temperature). Category 5 impaired waters do require a TMDL and in the case of coldwater lake assessments, this will likely involve a need to reduce TP loading. Differences in the actions needed to restore lakes based on the causative stressor means that making these determinations can be considered as part of the assessment process. Ensuring that appropriate stressor is targeted will result in better restoration and protection outcomes and greater efficiency with water quality resources.

The coldwater lake standards themselves can be informative regarding the 303(d) listing category. For example, a lake exceeding the T_{DO3} standard, but not the chl-*a* standard may be indicative of an impact of climate change and thereby could result in a category 4C on the 303(d) list. In contrast, an exceedance of both chl-*a* and T_{DO3} would indicate that nutrient loading is at least partially the cause of nonattainment. However, additional work may be needed to determine if rising temperatures are also impacting lake productivity and hypolimnetic oxygen through mechanisms such as increasing the length

of the growing season or increasing internal loading. This determination can be used to help direct management plans for the protection or restoration of lakes. However, disagreement between these indicators may be caused by other factors (e.g., dataset robustness, sampling variability, site-specific conditions) and these possible factors should be considered as part of the management of these lakes.

Table 17. Assessment categories for waters on the 303(d) list.

Category	Description
2	Waterbody's assessed designated uses are fully supported, the designated use is fully supported, or parameter meets standards.
3	Data insufficient or inconclusive to assess.
4A	Impaired and a TMDL study has been approved by EPA.
4B	Impaired but a TMDL study is not required because water quality standards are expected to be met in the near future.
4C	Impaired but a TMDL study is not required because the impairment is not caused by a pollutant.
4D	Impaired but a TMDL study is not required because the impairment is due to natural conditions with insignificant anthropogenic influence. To be considered insignificant, the elimination of the anthropogenic influence would not lead to the attainment of water quality standards and it would not be included in formal pollution reduction goal-setting activities. Category 4D indicates a site-specific water quality standard based on local natural conditions has yet to be determined.
4E	Impaired but existing data strongly suggests a TMDL study is not required because impairment is not caused by a pollutant or is due to natural conditions with only insignificant anthropogenic influence; a final determination of Category 4C or 4D will be made in the next assessment cycle pending confirmation from additional information.
5	Impaired and a TMDL study has not been approved by EPA.

The determination of TP criteria for the draft chl-*a* criterion differ from the methods used to determine the eutrophication criteria adopted in 2008 (Heiskary and Wilson 2005). The models in the original lake eutrophication criteria were least-squares regressions of log transformed TP and chl-*a* data. As a result, the model predicts that approximately half of lakes at a given TP value will exceed the chl-*a* criterion. The updated model for the coldwater lakes uses a 90th percentile loess regression to predict TP concentrations associated with chl-*a* thresholds needed to protect coldwater fish species (Figures 17 and 18). For lakes at the TP criterion, this model predicts 10% of lakes will exceed the chl-*a* standard. Although useful for assessment and ensuring that lake assessments do not result in inconclusive results due to a misalignment between TP and chl-*a* (i.e., false negative errors), this model is less useful for developing TMDLs. Developing TMDLs based on the model using a 90th percentile will result in targets for some lakes where lower nutrient load reductions will still achieve productivity targets. As a result, other models such as the BATHTUB model or models derived from the datasets used in Figures 17 and 18 can be used to develop lake-specific targets to meet standards when appropriate.

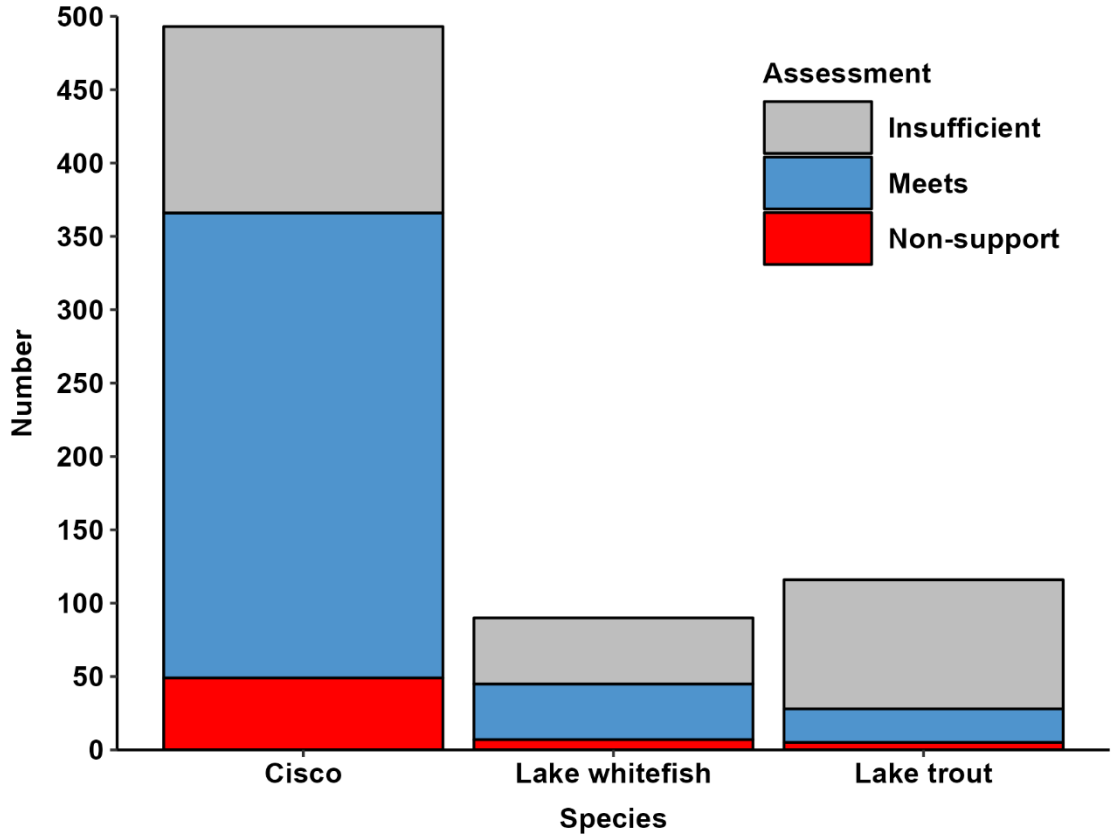
vi. Pilot assessments

The draft coldwater lake standards were used as part of an exercise to informally assess the condition of the lakes which will be designated as coldwater habitat. Based on species-specific thresholds for T_{DO3} and chl-*a*, lake data were compared against these thresholds. For this assessment 3 years of T_{DO3} and 2 years of chl-*a* data were required and any data available from 1990 through 2020 were included and averaged for each lake. Both parameters were considered together and a determination of "non-support" was based on one or both parameters indicating non-attainment of the thresholds. A determination of "meets" was based on both parameters meeting the thresholds or one parameter meeting and the other insufficient. Lakes that lacked sufficient data to assess either parameter were flagged as having "insufficient" data. It should be noted that this is a preliminary, informal assessment of

these draft thresholds. A full and formal assessment would be more detailed and would include additional considerations. For example, a formal assessment would restrict data to the most recent 10 years and include scrutiny of the data including sampling location, timing of sampling, and sample variability. Other considerations, especially for lakes near thresholds, may include review of fisheries data, watershed land use, lake morphology, ground water inputs, and other water quality data. As a result, the informal assessments used in this pilot analysis do not exactly reflect the actual outcomes of a formal assessment and these results should be treated as exploratory.

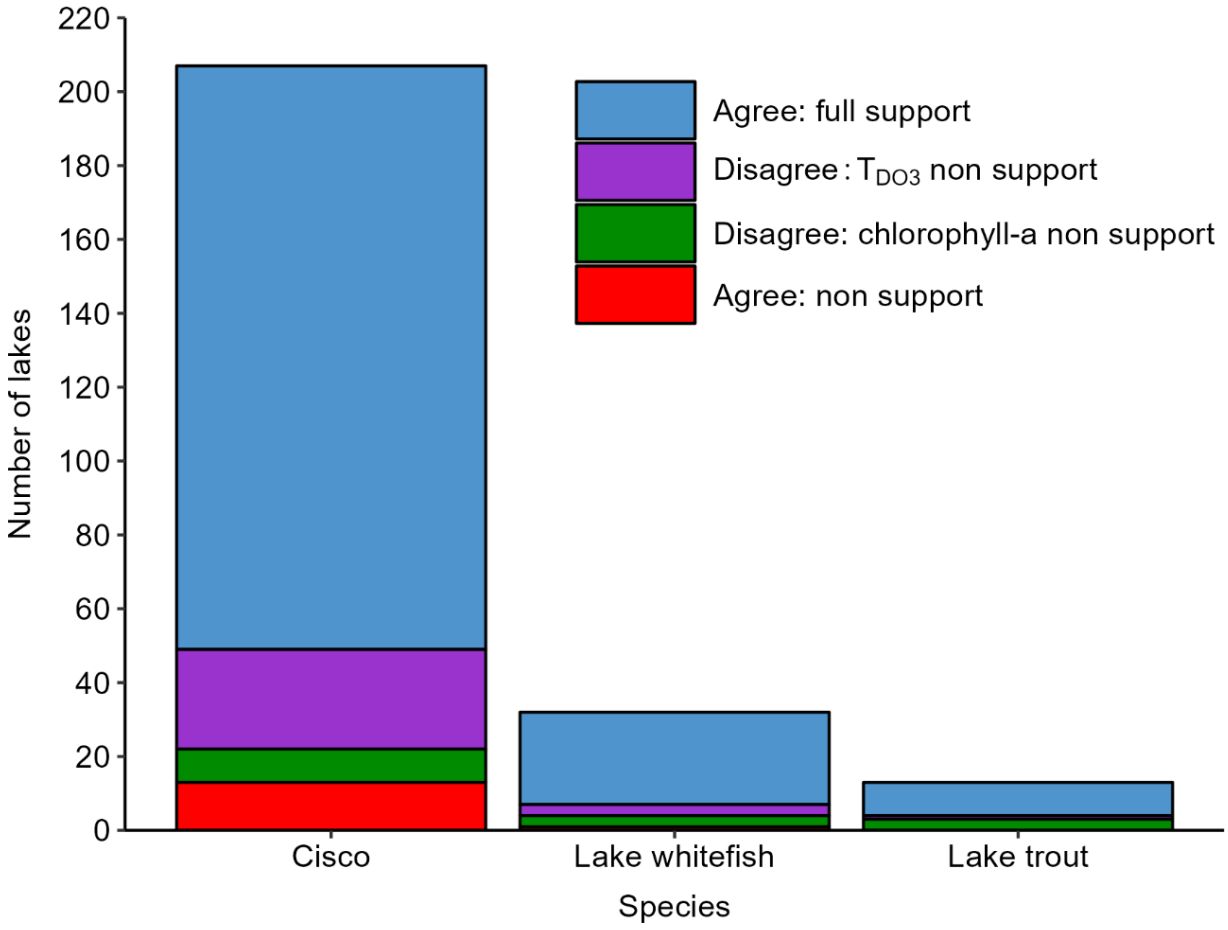
Exceedance rates of the draft coldwater habitat thresholds were generally low with 10%, 8%, and 4% of lakes not meeting one or both coldwater habitat indicators for Cisco, Lake Whitefish, and Lake Trout, respectively (Figure 24). In some cases, the lakes which exceeded the standard support good populations of coldwater taxa and site-specific standards may be needed to address atypical conditions in those lakes. Sixty-four percent of Cisco lakes had good water quality indicating conditions that should support this fish species. The proportion of lakes meeting thresholds for Lake Whitefish and Lake Trout were lower (42%: Lake Whitefish; 20%: Lake Trout) due to large number of lakes lacking sufficient data for assessment. The large proportion of lakes lacking data were because many Lake Whitefish and Lake Trout lakes are in far northern Minnesota in remote areas such as the Boundary Water Canoe Area Wilderness (BWCAW) and are difficult to sample. As a result, it could be predicted that many of these lakes are relatively undisturbed and likely have conditions supportive of these sensitive coldwater fish species. Overall, this analysis is consistent with expectations for Minnesota lakes supporting these fish species. Cisco are more widespread, including into more heavily developed portions of central Minnesota and would therefore be expected to have more non-supporting or threatened lakes despite their greater tolerance to temperature and lake productivity impacts. Lake Trout and Lake Whitefish are largely limited to areas with low disturbance in Minnesota and as expected there are fewer lakes that indicate poor water quality.

Figure 24. Informal assessment outcomes for coldwater lakes based on available T_{DO3} and chlorophyll-*a* data.



An assessment of the agreement between the two coldwater habitat indicators was also performed. For lakes with both sufficient chl-*a* and T_{DO3} data (n=221), these two indicators agreed for 82% of lakes (Figure 25). In a formal assessment, the agreement between these parameters will be higher due to better temporal alignment of data within a 10-year window and data reviews that determine one indicator is a better measure of coldwater habitat or SSS which revise one indicator due to atypical conditions. In addition, there are more disagreements where T_{DO3} indicates non-support while chl-*a* indicates support. In these cases, temperature impacts may be more important than nutrient loading. Overall, these indicators are useful when used in conjunction for assessments as they can be used to confirm non-attainment when they are aligned. When these indicators disagree, information on the condition of a lake can be obtained or it can be used as a flag for additional examination or monitoring.

Figure 25. Comparison of assessment outcomes for coldwater lakes with sufficient T_{DO3} and chlorophyll-*a* data for assessment.



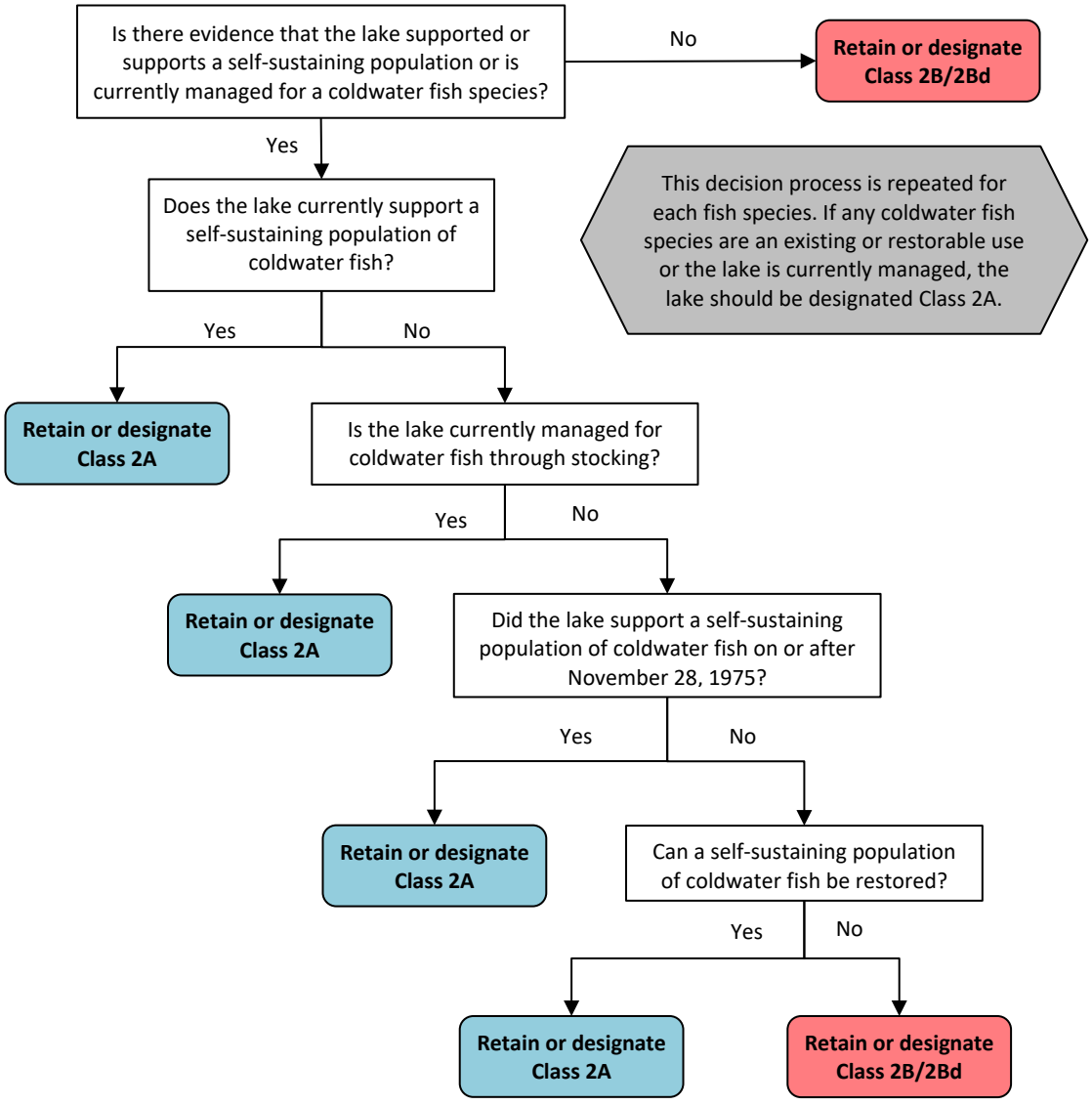
Coldwater lake habitat use designation reviews

Establishing criteria for the protection of coldwater habitats is only one part of WQS and the implementation of protection and restoration strategies. A second important element of WQS is the designation of beneficial uses. A beneficial or designated use determines which standards are applicable to a lake and is therefore critical to ensuring that the correct standards are applied. In the case of the draft coldwater lake standards, this requires a determination of which coldwater fish species are protected in a lake. The determination of the appropriate coldwater designation is largely driven by historical and contemporary biological data although several additional lines of evidence are also important for making use designation decisions. These use designation reviews consider existing and

attainable aquatic life uses and rely on an assessment of factors, both natural and anthropogenic, that determine the suitably for a lake to support coldwater fish species.

Determining the species that need to be protected by a coldwater habitat designation in a lake are driven by the determination that the lake supports a self-sustaining population of that species or that the lake is currently managed[15] for that species. An important element of use designation reviews is the concept of "existing use." Existing uses are beneficial uses attained on or after November 28, 1975 (Minn. R. 7050.0255, subp. 14). This means that a use attained on or after that date, even if lost, must be retained. However, if a use was lost before that date and cannot be restored, it is not an existing use. An overview of the process for reviewing coldwater lake designations is in Figure 26 and a more detailed process chart is in Appendix B. Although these processes are described in these figures as a stepwise or linear process, these considerations are often iterative.

Figure 26. Clean Water Act beneficial use designation review decision process for coldwater lakes.



[15] In most cases, this involves fish stocking by the MNDNR to maintain or supplement the fish population.

A determination that a Lake Trout, Lake Whitefish, or Cisco population is an existing use that should be protected by a coldwater habitat designation is largely based on a determination that a lake supports a native or resident population that does not rely on stocking to sustain the population. However, this is not always the case, particularly for Lake Trout, which have been introduced into many lakes and where self-sustaining populations are now established. There are also a relatively small number of lakes where Cisco were stocked and have now become established. As a result, lakes with natural or introduced populations of coldwater species which become established and self-sustaining are existing uses and would need to be maintained even if a species was extirpated. There are some lakes which are managed for Lake Trout where the maintenance of that population depends on stocking. It is appropriate to maintain or add protections for coldwater species when that species is present, even when the population is maintained through stocking[16]. However, a situation where the population is naturally not self-sustaining and is reliant on stocking may not constitute an existing use and the cessation of stocking could result in the removal of that use.

Use designations for lakes protected for stream trout are similar to lakes with other coldwater species where the population is maintained through stocking. Most stream trout lakes only support trout because they are managed for these species through stocking. There are a small number of lakes in Minnesota that contain stream trout not because of stocking, but due to connections to coldwater streams supporting trout. In most cases, lakes with natural populations of trout (usually Brook Trout) are shallow and are only used seasonally by trout. Since most stream trout lakes only support trout due to stocking, the cessation of management results in the loss of these populations. When managed, stream trout lakes do not support a natural population and therefore are not an existing use.

The status and type of a coldwater fish population are general considerations that form the basis for coldwater lake use designation reviews, but these decisions rely on detailed lake information including fisheries surveys, lake morphology, and natural water quality. The following sections describe these considerations in detail. In addition, specific examples of coldwater habitat reviews are in Appendix C.

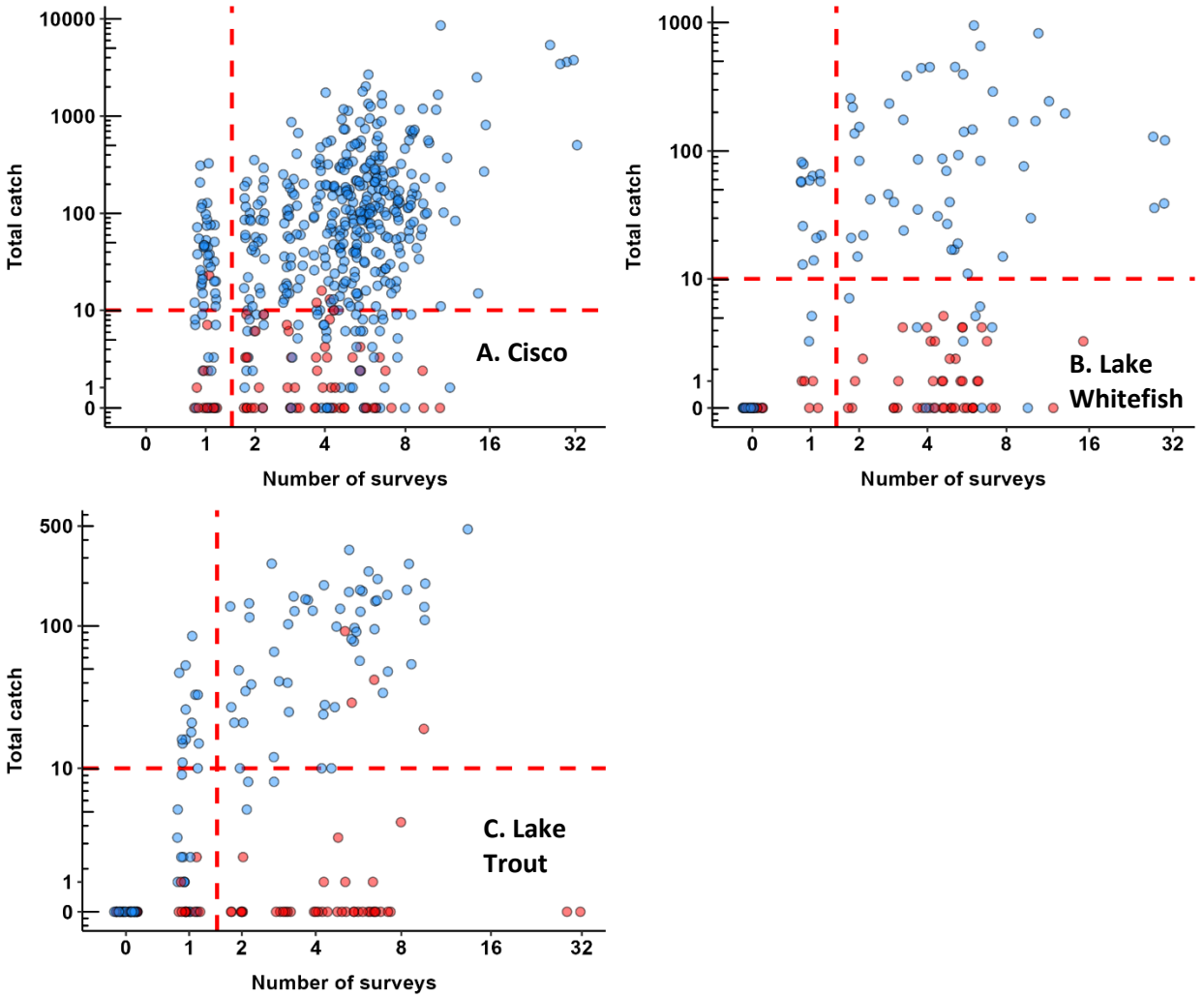
i. Fisheries surveys

The presence of a self-sustaining population of a coldwater fish species, whether contemporary or historical, are of primary importance for determining use designations[17]. MNDNR fisheries surveys are the most important line of evidence for establishing the status of populations of coldwater fishes for determining the appropriate use designation for a lake. For these use designation reviews, screening criteria have been developed to determine assignment of coldwater fish designations. A flow chart describing this, and other steps is provided in Appendix B. The number of surveys and the number of coldwater fish sampled are used to initially screen lakes. Lakes that have been surveyed at least twice and where surveys have sampled at least 10 individuals of a coldwater species typically indicate support for populations of coldwater fishes (Figure 27). Although this guideline is useful for screening lakes for coldwater designation, it is only one line of evidence that may be used for determining a fish population's status.

[16] There may be exceptions to this scenario if it is determined that coldwater habitat standards are not needed to maintain a heavily managed fishery. For example, a seasonal, put-and-take fishery for stream trout may not require coldwater habitat standards to support fishery goals.

[17] There are some cases where lakes that do not currently support self-sustaining populations of coldwater fish should be designated for the protection of these fishes. These include lakes that are managed for stream trout, some lakes where lake trout populations are maintained through stocking, lakes where self-sustaining populations of coldwater fish were extirpated on or after November 28, 1975, and lakes where self-sustaining populations of coldwater fish can be restored.

Figure 27. Classification of (A) Cisco, (B) Lake Whitefish, and (C) Lake Trout lakes based on number of fisheries surveys and total catch for lakes with draft designations (blue points) and lakes with an unknown fish population status (red points). Red dashed lines indicate guidelines for determination of coldwater fish population status. Dataset includes only dimictic lakes as determined by geometry ratio (<4).



Most MNDNR fisheries surveys consist of the use of standard gill nets which are not specifically deployed to estimate coldwater fish populations because these nets are typically set at or above the thermocline. Such data are useful at a lake population level but can be more difficult to use for specific lakes due to sampling variability. There is also variability in fisheries surveys due to natural variability and sampling error. As a result, it is often important to consider other evidence in use designation decisions especially when a limited number of surveys are available. There are other factors that should be considered as part of a coldwater habitat review including (1) whether fish are transient, (2) fish identification certainty, (3) stocking records, (4), if special, targeted surveys have been performed, and (5) other supporting information.

(1) Transient fish: There are many lakes in Minnesota from which coldwater fish have been surveyed, but the presence of these fish does not necessarily indicate the existence of a coldwater habitat. There are lakes where fish are transient from another coldwater habitat and are using the habitat during periods when conditions are suitable (e.g., spring/fall) or they represent stochastic migration. As a result, their presence does not represent the existence of a coldwater habitat and application of coldwater standards would not be appropriate. The determination of fish population status when these

fish are sampled from a lake include review of fisheries status from connected lakes, lake oxythermal habitat, and detailed review of the fisheries surveys. For example, if a lake is reviewed and it is determined that the geometry ratio is high or oxythermal habitat is limited, but the lake has a strong connection to a lake with good coldwater habitat that supports this coldwater fish species, then that may be used as evidence that the individuals sampled are transient. The lake surveys themselves may be useful if catches are small and irregular or if catches consist only of few large individuals, which can indicate a lack of recruitment in the lake. For examples see Farm Lake (38-0779-00) and Shagawa Lake (69-0069-00) in Appendix C.

(2) Fish identification: In some cases, fisheries surveys contain incorrect identifications especially between Cisco and Lake Whitefish. Vouchers are often not collected, but clues to incorrect identifications can often be detected from the available data. For example, a single Lake Whitefish identified from among several surveys containing only Cisco, may be a misidentification due to the presence of a large Cisco. In some cases, lakes with many fisheries surveys with Cisco will have a single survey which includes only Lake Whitefish. If this is the only survey in which Lake Whitefish were sampled, this is an indication of a misidentification. For examples see Alice Lake (38-0330-00), Shagawa Lake (69-0069-00), Gilstad Lake (04-0024-00), Big Sandy Lake (01-0062-00), and Charlotte Lake (77-0120-00) in Appendix C.

(3) Stocking records: Historical stocking records can be useful to understand the status of a fish population and if that population was self-sustaining. For example, if the presence of a coldwater fish species in fisheries surveys corresponds to a period when that species was stocked and surveys following the cessation of stocking did not sample that species, it could be an indication that the fish population was not self-sustaining. MNDNR fisheries surveys also often include information on whether sampled fish were stocked, or the result of natural reproduction based on fin clips or year class which can be useful for determination of population status. Such considerations can be important for the determination of an existing use. For examples see Alton Lake (16-0622-00), Bone Lake (38-0065-00), Ahsub Lake (38-0516-00), Eddy Lake (38-0187-00), and Johnson Lake (69-0691-00) in Appendix C.

(4) Targeted surveys: A subset of lakes have been surveyed using methods targeted to coldwater fishes such as vertical gill nets, deep-set gill nets, or hydroacoustic sampling. When data from these survey types are available, they may be given greater weight since they can better estimate populations of some coldwater fish species. For examples see Little McDonald Lake (56-0328-00), Scalp Lake (56-0358-00), West Battle Lake (56-0239-00), LaSalle Lake (29-0309-00), and Boot Lake (03-0030-00) in Appendix C.

(5) Supporting information: Some lakes have limited fisheries survey data, or the available fisheries data may be inconclusive, but other lines of evidence may be available to support a use designation decision. These lines of evidence may include oxythermal measures, lake morphology, creel surveys, and records from commercial fishing catches. If a small number of fisheries surveys are present, the size of the catches can be considered. For example, a single survey with a large catch of a coldwater fish species may be good evidence for the presence of a population of that fish. The catch size should also be considered in relation to the number of net sets that were part of the survey. A range of size classes for a fish species in a survey can also be useful to indicate that a resident population is present. There are many potential coldwater lakes in Minnesota with limited fisheries data. For example, many lakes supporting coldwater fishes are found in remote areas of northern Minnesota, including the BWCAW and Voyageurs National Park. For these lakes it may be appropriate to make use designation decisions based on limited data depending on the strength of available data and other lines of evidence. This may include a single survey with many coldwater fish present coupled with measures that indicate good oxythermal habitat or other lines of evidence. For examples see Eddy Lake (38-0187-00), Alice Lake (38-0330-00), Ashdick Lake (38-0210-00), and Harriet Lake (38-0048-00) in Appendix C.

ii. Lake mixing status

Following identification of the possible presence of a coldwater fish species population, determining the mixing status of the lake is important, especially for lakes where fisheries data are limited or not conclusive. Most lakes that support coldwater fish species in Minnesota are stratified[18]. To screen for dimictic lakes, a geometry ratio is used where lakes with a value of <4 are considered likely to be dimictic. For lakes near this threshold, additional data may also be considered. If summer temperature profiles exist for a lake they can be examined to determine if the lake is stratified. Typically, if a lake has more than a 1 °C/m change in the profile, it can be considered stratified. Even if a lake has data that indicate it stratifies or parts of the lake stratify, the size of this area should also be considered. Small, deep lakes may not provide suitable habitat for some fish species such as Lake Trout and should not be designated as coldwater habitat for Lake Trout unless there is active management for that species. In addition, for large, complex lakes, it should be determined if only part of the lake is likely to be suitable for coldwater fishes and to ensure that data used for the designation decision is from these suitable areas.

iii. Other evidence

Reviewing water quality data, especially dissolved oxygen, is important to establish if sufficient coldwater habitat is present in a lake. In addition to cool temperatures, coldwater fish species rely on sufficient levels of oxygen for survival and dissolved oxygen profiles can be instrumental for determining habitat suitability. Dissolved oxygen in a lake can be impacted by cultural eutrophication so how natural the dissolved oxygen conditions are may need to be considered through this lens especially when determining the designated use for a lake where coldwater fish have been extirpated. Land use and other measures of human activity may need to be reviewed to determine if a lake's dissolved oxygen profile or trophic state are natural. If trophic conditions in a lake have been degraded, then the timing of this degradation and whether it contributed to the extirpation of coldwater fishes will need to be assessed. For example, if the degradation occurred before November 28, 1975, and it cannot be reversed then it may be appropriate to not designate a lake for the protection of a coldwater fish species. In contrast, if the degradation occurred after the existing use date or the fish population can be restored, then the lake should be designated for the protection of that fish species.

iv. Review of current coldwater use designations

Review of the coldwater habitat designation for a lake includes consideration of the existing designation applied to a lake. Coldwater habitat designations for lakes under the current framework includes two classifications: 1) Lake Trout and 2) stream trout lakes. The reviews in this rule revision consider whether the current trout classification is appropriate in regard to the species protected or managed and if additional coldwater species need to be added to the list of protected species. This review includes consideration of existing use and whether native, self-sustaining populations of these fish species were present on or after November 28, 1975, or if that population could be feasibly restored. In some cases, a coldwater fish species may be extirpated and not restorable, but if that species was self-sustaining on or after the existing use date, the protections for that species remain. The most common situation in Minnesota with this scenario are lakes where Rainbow Smelt have been introduced and the native

[18] There are a relatively small number of polymictic lakes which support populations of coldwater fish species, but the draft standards are not applicable to these lakes. As a result, the use designation reviews do not currently consider these lakes for designation. Standards need to be developed for these lakes before they are included for designation. See Appendix D.

coldwater fish populations have been extirpated. However, due to a warming climate in Minnesota, unrestorable losses of these coldwater fish populations are predicted to become more common (Sharma et al. 2011, Fang et al 2012, Jiang et al. 2012, Jiang et al. 2017).

The removal of protections for a current coldwater fish species is often due to the collection of new data. Previous designations, especially for Lake Trout, may have been based on limited information and a prediction that these lakes had the potential to support Lake Trout without extensive evidence to confirm the designation. In many cases these were lakes in the remote areas such as the BWCAW where limited fishery or water quality data were available. In some cases, stream trout lakes were also designated based on a potential to manage the lake as a stream trout fishery, but due to limiting factors (e.g., competition with other fish species or limited public access) it was determined to not be feasible, and management ended. Most designations where protections for a fish species are removed or a lake is designated Class 2Bd are due to the availability of new data and the need to make a correction to the designation. Very few designations in these draft revisions are for lakes with confirmed populations of coldwater fish which were extirpated before the existing use date.

The third element of WQS is antidegradation and it directly impacts coldwater habitat designations. Specifically, Lake Trout lakes outside of the BWCAW or Voyageurs National Park are designated restricted outstanding resource value waters (Minn. R. 7050.0335, subp. 1, Item C). As part of the review of coldwater designations, Outstanding Resource Value Water (ORVW) designations are also reviewed to determine if the ORVW should be added or removed and which ORVW should be applied (i.e., restricted or prohibited ORVW). It is not necessary for lakes within the BWCAW or Voyageurs National Park to be reviewed because these waters are prohibited outstanding resource value waters (Minn. R. 7050.0335, subp. 3) regardless of whether they are designated as a Lake Trout lake. The other coldwater fish protections (i.e., Cisco, Lake Whitefish, and stream trout) do not affect the ORVW designation for lakes.

Rule language changes

Rule revisions for the protection of coldwater fish communities will likely include amendments to Minn. R. 7050.0150, 7050.0222, and 7050.0470. The revisions to Minn. R. 7050.0150 should include new definitions for “oxythermal layer,” and for “dimictic” and “polymictic” lakes. The draft standards are specifically designed to protect lakes that support or should support 1) Lake Trout, 2) Lake Whitefish, and 3) Cisco or are managed for 4) stream trout. For each lake type, there are specific eutrophication and oxythermal standards and these standards will need to be described in Minn. R. 7050.0222. Specifically, these revisions include the addition of eutrophication standards (i.e., TP, chl-*a*, and Secchi depth) and T_{DO3} standards for two coldwater fish species (i.e., Lake Whitefish and Cisco). In addition, a T_{DO3} standard will be added for Lake Trout and two eutrophication parameters (TP and Secchi depth) will be revised based on new models for Lake Trout and stream trout lakes. The addition of the T_{DO3} standards may also require additional language to explain the application of the dissolved oxygen standard. For example, it may be appropriate for the existing dissolved oxygen standard for Class 2A (i.e., 7 mg/L) to only apply to streams whereas the T_{DO3} standards would apply to coldwater lake habitats only.

The amendments to Minn. R. 7050.0470 consist of two elements. First, the amendments will create tables incorporated by reference to store use designation information. This would bring the lakes in alignment with the system currently used for stream designations (see https://www.pca.state.mn.us/regulations/incorporations-reference). The second part of revisions to Minn. R. 7050.0470 would designate specific uses to lakes (see Appendix C). This includes Class 2A, 2B, and 2Bd designations as well as the addition of species codes to describe in the rule which coldwater

fish species are protected in each designated coldwater lake. Class 1B designations will also be added to lakes designated as Class 2A.

There are other related and needed amendments that will likely be associated with the revision of coldwater lake standards and use designations. This includes revisions to northern lake eutrophication standards and the adoption of a tiered aquatic life uses (TALU) framework for lakes. These revisions include complementary changes such as adding language to define dimictic and polymictic lakes to rule (MPCA 2024b). The TALU framework for lakes will affect the lakes in the coldwater lakes revision by placing them into General and Exceptional Use tiers (MPCA 2024c). Upon adoption of a TALU lakes rule, the "e" and "g" designators will be added to the Class 2A, 2Bd, and 2B designations in Minn. R. 7050.0470 to acknowledge the different levels of biological condition for fish communities in these lakes. The TALU framework for lakes will also include the adoption of tiered fish biological criteria. Although these biological criteria were developed to largely measure the health of warm water fish communities in lakes, these criteria will also be applicable to coldwater lakes. This is because coldwater lakes support both coldwater and warm water communities of fish. For this reason, these lakes are sometimes called two-story lakes. In Minnesota's coldwater lakes, it is important that the warm water fish community is protected through specific biological and chemical standards and the coldwater community is managed using its own specific standards. In some cases, there will be multiple standards for the same parameter in lakes. For example, there may be eutrophication standards for both the protection of the warm water (see MPCA 2024b) and coldwater fish communities. In this case, the more stringent standards will be used to assess the status of the lake to ensure that the more sensitive portion of the community is protected. In addition, other minor changes may also be needed as part of a lake standards rule package. Through these revisions, Minnesota's lake standards will be more comprehensive in terms of protections for aquatic life and recreation in lakes.

Conclusions

The draft criteria for oxythermal habitat and eutrophication establish a framework of minimum conditions required to protect coldwater lake habitats in Minnesota. The criteria consist of an oxythermal habitat measure (i.e., T_{DO3}) and a set of eutrophication parameters including TP, chl-*a*, and Secchi depth (Table 13). T_{DO3} measures the condition of coldwater habitat and is affected by temperature and lake productivity whereas the eutrophication criteria are largely reflective of lake productivity. Together these standards can be used in conjunction to reduce missed impairments and to improve assessment accuracy. These standards are based on protections for three coldwater fish species (i.e., Lake Trout, Lake Whitefish, and Cisco) and a group of stream trout species and hybrids which are managed in a subset of Minnesota's lakes. Minnesota's existing standards for eutrophication include protections for Lake Trout and stream trout and changes to these standards include the inclusion of T_{DO3} criteria for Lake Trout and revisions to the TP and Secchi depth criteria for both lake and stream trout lakes. The currently adopted chl-*a* criteria would be unchanged for Lake Trout and stream trout lakes. Protections for other Minnesota salmonids including Cisco and Lake Whitefish were identified as a gap in WQS which these draft criteria would address. It was determined that like other salmonids, Cisco and Lake Whitefish are sensitive to increasing temperatures and declining dissolved oxygen. As a result, T_{DO3} and chl-*a* criteria will also be assigned to lakes which support these sensitive fish species. As part of eutrophication water quality standards for Cisco and Lake Whitefish lakes, TP and Secchi depth criteria are also included.

In addition to providing revised standards to protect coldwater fish species, this research also includes another important element of WQS: beneficial use designations. We have reviewed available data to determine which lakes support or are managed for these coldwater fish species. Use designations for 732 coldwater lakes will be confirmed or modified as part of this review including the addition of 410

Class 2A lakes and removal of 25 Class 2A lakes. The result is a comprehensive list of lakes with coldwater habitat for which these standards should apply. This includes a determination of the fish species that are supported or should be supported in these lakes. In doing so, WQS can be precisely applied to these lakes such that criteria specific to the taxa found in the lake can be protected. As with other WQS, the criteria for the most sensitive use (i.e., fish species) will be the applicable coldwater standards for a lake. The evidence supporting the draft coldwater use designations are described in Appendix C.

This report provides sufficient and reasonable technical information for amending use designations. These use designation lists coupled with the draft criteria for coldwater habitats can be implemented through or used to enhance existing programs such as the MPCA's Intensive Watershed Monitoring framework and Watershed Restoration and Protection Strategies and the MNDNR's Cisco Refuge Lakes, Lakes of Biological Significance, and Lakes of Phosphorus Sensitivity programs. In most cases this will require lakeshed protections to limit or reduce TP loading to these lakes through best management practices and maintaining natural landscapes. Unfortunately, climate change is likely to significantly increase temperature in Minnesota in the coming decades which alone will result in the loss of many coldwater habitats and the extirpation of coldwater fish species from some lakes. Cultural eutrophication of coldwater lakes also threatens these species which will require long-term planning to limit or reduce nutrient loading to these lakes. The interactive effects of rising temperatures and lake productivity will also exacerbate these challenges. However, coldwater fishes are important and valuable components of many Minnesota lakes and their loss will degrade Minnesota's natural and cultural ecosystems. These fish and their habitats are worth protecting and the draft coldwater lake standards along with other protection strategies provide a framework for preserving these resources.

References

Aku, P. and W. Tonn, 1997. Changes in population structure, growth, and biomass of cisco (*Coregonus artedi*) during hypolimnetic oxygenation of a deep, eutrophic lake, Amisk Lake, Alberta. Canadian Journal of Fisheries and Aquatic Sciences 54: 2196-2206.

Aku, P., L. Rudstam, and W. Tonn, 1997. Impact of hypolimnetic oxygenation on the vertical distribution of cisco (*Coregonus artedi*) in Amisk Lake, Alberta. Canadian Journal of Fisheries and Aquatic Sciences 54: 2182-2195.

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

Bernatchez, L. and J. J. Dodson, 1985. Influence of temperature and current speed on the swimming capacity of lake whitefish (*Coregonus clupeaformis*) and cisco (*C. artedii*). Canadian Journal of Fisheries and Aquatic Sciences 42: 1522-1529.

Cahn, A.R. 1927. An ecological study of southern Wisconsin fishes, the brook silverside and the cisco, in their relation to the region. Illinois Biological Monographs 11.

Carlander, K.E. 1969. Handbook of freshwater fishery biology, Volume one, 3rd edition. Iowa State University Press, Ames, Iowa 752 p. [Cited in Wismer and Christie (1987)]

Clark, B.J., P.J. Dillon, and L.A. Molot, 2004. Lake trout (*Salvelinus namaycush*) habitat volumes and boundaries in Canadian Shield Lakes. In J.M. Gunn, R.J. Steedman, and R.A. Ryder (eds.), Boreal shield waters: lake trout ecosystems in a changing environment. Lewis Publishers, CRC Press, Boca Raton, Fla. pp. 111–117.

Clark, B., P. Dillon, L. Molot, and H. Evans, 2002. Application of a hypolimnetic oxygen profile model to lakes in Ontario. Lake and Reservoir Management 18: 32-43.

Cormier, S.M. and G.W. Suter II, 2013. A method for deriving water-quality benchmarks using field data. Environmental toxicology and chemistry 32(2): 255-262.

Coutant, C.C., 1977. Compilation of temperature preference data. Journal of the Fisheries Research Board of Canada 34: 739-745.

Custer, C.A., J.S. North, E.M. Schliep, M.R. Verhoeven, G.J. Hansen, and T. Wagner, 2024. Predicting responses to climate change using a joint species, spatially dependent physiologically guided abundance model. Ecology e4362.

Davis, J.C., 1975. Waterborne dissolved oxygen requirements and criteria with particular emphasis on the Canadian environment. Associate Committee on Scientific Criteria for Environmental Quality, Report No. 13. National Research Council of Canada. 111p.

De Stasio Jr, B.T., D.K. Hill, J.M. Kleinhans, N.P. Nibbelink, and J.J. Magnuson, 1996. Potential effects of global climate change on small north-temperate lakes: Physics, fish, and plankton. Limnology and oceanography 41(5): 1136-1149.

Edsall, T.A., 1999. Preferred temperatures of juvenile lake whitefish. Journal of Great Lakes Research 25: 583-588.

Edsall, T.A., and T.J. DeSorcie, 2002. The growth-temperature relation and preferred temperatures of juvenile lake herring. Advances in Limnology 57: 335-342.

Edsall, T.A. and D.V. Rottiers, 1976. Temperature tolerance of young-of-the-year lake whitefish, *Coregonus clupeaformis*. Journal of the Fisheries Research Board of Canada 33: 177–180.

EPA. 2000. Nutrient criteria technical guidance manual: Lakes and reservoirs. United States Environmental Protection Agency, Washington, D.C.

EPA. 2021. Ambient water quality criteria to address nutrient pollution in lakes and reservoirs. EPA-822-R-21-005. Office of Science and Technology, Office of Water, United States Environmental Protection Agency, Washington, D.C.

Etnier, D.A. and C.E. Skelton, 2003. Analysis of three cisco forms (*Coregonus*, Salmonidae) from Lake Saganaga and adjacent lakes near the Minnesota/Ontario border. Copeia 2003: 739-749.

Evans, D.O., J. Casselman, and C. Willox, 1991. Effects of exploitation, loss of nursery habitat, and stocking on the dynamics and productivity of lake trout populations in Ontario lakes: Lake trout synthesis, response to stress working group. Ontario Ministry of Natural Resources.

Evans, D.O., K.H. Nicholls, Y.C. Allen, and M.J. McMurtry, 1996. Historical land use, phosphorus loading, and loss of fish habitat in Lake Simcoe, Canada. Canadian Journal of Fisheries and Aquatic Sciences 53: 194-218.

Fang, X., L. Jiang, P.C. Jacobson, H.G. Stefan, S.R. Alam, and D.L. Pereira, 2012. Identifying cisco refuge lakes in Minnesota under future climate scenarios. Transactions of the American Fisheries Society 141: 1608-1621.

Ferguson, R.G., 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. Journal of the Fisheries Board of Canada 15(4): 607-624.

Fry, F.E.J., 1937. The summer migration of the cisco, (*Leucichthys artedi*) (LeSueur), in Lake Nippissing, Ontario. University of Toronto studies - Biological series, No. 11 (Publication of the Ontario Fisheries Research Laboratory, No.55), 91 pp. [Cited in Coutant (1977)]

Galligan, J.P. 1951. The distribution of lake trout and associated species in Cayuga Lake. M.S. Thesis. Cornell University, New York. 112 pp. [Cited in Coutant (1977)]

Galligan, J.P., 1962. Depth distribution of lake trout and associated species in Cayuga Lake, New York. New York Fish and Game Journal 9: 44-68. [Cited in Martin and Oliver (1980)]

Goddard, C., J. Lilley, and J. Tait, 1974. Effects of MS 222 anesthetization on temperature selection in lake trout, *Salvelinus namaycush*. Journal of the Fisheries Board of Canada 31: 100-103.

Gorsky, D., J. Zydlewski, and D. Basley, 2012. Characterizing seasonal habitat use and diel vertical activity of lake whitefish in Clear Lake, Maine, as determined with acoustic telemetry. Transactions of the American Fisheries Society 141: 761-771.

Hansen, G.J., K.E. Wehrly, K. Vitense, J.R. Walsh, and P.C. Jacobson, 2022. Quantifying the resilience of coldwater lake habitat to climate and land use change to prioritize watershed conservation. Ecosphere 13: p.e4172.

Hanson, P.C., D.L. Bade, S.R. Carpenter, and T.K. Kratz, 2003. Lake metabolism: Relationships with dissolved organic carbon and phosphorus Limnology and Oceanography 48(3): 1112-1119.

Hatch, J., 2015. Minnesota fishes: just how many species are there anyway? American Currents 40: 10-21.

Havens, S., M. Rennie, P. Blanchfield, M. Paterson, and S. Higgins, 2014. Evaluation of eutrophication and water level drawdown on Lake Whitefish (*Coregonus clupeaformis*) productivity; Fish habitat assessment. Canadian Technical Report of Fisheries and Aquatic Sciences 3110: vi + 40 p.

Heegaard, D., 2002. The outer border and central border for species–environmental relationships estimated by non-parametric generalised additive models. Ecological Modelling 157(2-3): 131–139.

Heiskary, S. and C.B. Wilson, 2005. Minnesota lake water quality assessment report- developing nutrient criteria: third edition, MPCA, St. Paul, MN.

Herb, W.R., L.B. Johnson, P.C. Jacobson, and H.G. Stefan, 2014. Projecting cold-water fish habitat in lakes of the glacial lakes region under changing land use and climate regimes. Canadian journal of fisheries and aquatic sciences 71: 1334-1348.

Hoagman, W.W., 1974. Vital activity parameters as related to the early life history of larval and post-larval whitefish (*Coregonus clupeaformis*). In J.H.S. Blaxter (ed.), The Early Life History of Fish. Springer-Verlag, New York, NY. [Cited in Jobling (1981) and Coutant (1977)]

Honsey, A.E., S.B. Donabauer, and T.O. Höök, 2016. An analysis of lake morphometric and land-use characteristics that promote persistence of cisco in Indiana. Transactions of the American Fisheries Society 145: 363-373.

Hosmer Jr, D.W., S. Lemeshow, and R.X. Sturdivant, 2013. Applied logistic regression (3rd ed.). John Wiley & Sons, Hoboken, NJ, USA.

Jacobson, P.C., T.K. Cross, J. Zandlo, B.N. Carlson, and D. Pereira, 2012. The effects of climate change and eutrophication on cisco *Coregonus artedi* abundance in Minnesota lakes. Advances in Limnology 63: 417-427.

Jacobson, P.C., T.S. Jones, P. Rivers, and D.L. Pereira, 2008. Field estimation of a lethal oxythermal niche boundary for adult ciscoes in Minnesota lakes. Transactions of the American Fisheries Society 137: 1464-1474.

Jacobson, P.C., G.J. Hansen, L.G. Olmanson, K.E. Wehrly, C.L. Hein, and L.B. Johnson, 2019. Loss of coldwater fish habitat in glaciated lakes of the midwestern United States after a century of land use and climate change. In R.M. Hughes, L. Wang, K. Chen, and B. F. de Terra (eds.), Advances in understanding landscape influences on freshwater habitats and biological assemblages. American Fisheries Society, Bethesda, MD. pp. 141-158.

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., K.D. Zimmer, R., Grow, and R.L. Eshenroder 2020. Morphological variation of cisco across gradients of lake productivity. Transactions of the American Fisheries Society, 149(4), 462-473.

Jane, S.F., G.J. Hansen, B.M. Kraemer, P.R. Leavitt, J.L. Mincer, R.L. North, and K.C. Rose, 2021. Widespread deoxygenation of temperate lakes. Nature 594(7861): 66-70.

Jiang, L. and X. Fang, 2016. Simulation and validation of cisco lethal conditions in Minnesota lakes under past and future climate scenarios using constant survival limits. Water 8(7): 279.

Jiang, L., X. Fang, and G. Chen, 2017. Refuge lake reclassification in 620 Minnesota cisco lakes under future climate scenarios. Water 9: 675.

Jiang, L., X. Fang, H.G. Stefan, P.C. Jacobson, and D.L. Pereira, 2012. Oxythermal habitat parameters and identifying cisco refuge lakes in Minnesota under future climate scenarios using variable benchmark periods. Ecological modelling 232: 14-27.

Johnson, L., 1975. Distribution of fish species in Great Bear Lake, Northwest Territories, with reference to zooplankton, benthic invertebrates, and environmental conditions. Journal of the Fisheries Board of Canada 32: 1989-2004. [Cited in Martin and Oliver (1980)]

Kaufman, S.D., G.E. Morgan, and J.M. Gunn, 2009. The role of ciscoes as prey in the trophy growth potential of walleyes. North American Journal of Fisheries Management 29: 468-477.

Kennedy, P., T. Bartley, D. Gillis, K. McCann, and M. Rennie, 2018. Offshore prey densities facilitate similar life history and behavioral patterns in two distinct aquatic apex predators, northern pike and lake trout. Transactions of the American Fisheries Society 147: 972-995.

Koelz, W., 1931. The coregonid fishes of North-Eastern America. Papers of the Michigan Academy of Science, Arts, and Letters 13: 303-432.

Koenker, R., 2019. quantreg: Quantile Regression. R package version 5.54. https://CRAN.R-project.org/package=quantreg

Kritzberg, E., J.J. Cole, M.L. Pace, W. Granéli, and D.L. Bade, 2004. Autochthonous versus allochthonous carbon sources of bacteria: Results from whole-lake 13C addition experiments. Limnology and Oceanography 49(2): 588-596.

Lyons, J., T.P. Parks, K.L. Minahan, and A.S. Ruesch, 2017. Evaluation of oxythermal metrics and benchmarks for the protection of cisco (*Coregonus artedi*) habitat quality and quantity in Wisconsin lakes. Canadian Journal of Fisheries and Aquatic Sciences 75: 600-608.

Mac, M. J., 1985. Effects of ration size on preferred temperature of lake charr *Salvelinus namaycush*. Environmental Biology of Fishes 14: 227-231.

MacLean, N., J. Gunn, F. Hicks, P. Ihessen, M. Malhiot, T. Mosindy, and W. Wilson, 1990. Genetic and environmental factors affecting the physiology and ecology of lake trout. Ontario Ministry of Natural Resources, Toronto, Ontario.

Madenjian, C. P., D.V. O'Connor, S.A. Pothoven, P.J. Schneeberger, R.R. Rediske, J.P. O'Keefe, R.A. Bergstedt, R.L. Argyle, and S.B. Brandt, 2006. Evaluation of a lake whitefish bioenergetics model. Transactions of the American Fisheries Society 135(1): 61-75.

Martin, N. V., 1952. A study of the lake trout, *Salvelinus namaycush*, in two Algonquin Park, Ontario, lakes. Transactions of the American Fisheries Society 81: 111-137.

Martin, N. and C. Oliver, 1976. The distribution and characteristics of Ontario lake trout lakes. Ontario Ministry of Natural Resources Report 97, 30 pp. [Cited in Martin and Oliver (1980)]

Martin, N. and C. Oliver, 1980. The lake charr, *Salvelinus namaycush*. In E.K. Balon (ed.), Charrs: Salmonid Fishes of the Genus *Salvelinus*. Kluwer, Boston, MA. pp. 205–277.

Matuszek, J.E., B.J. Shuter, and J.M. Casselman, 1990. Changes in lake trout growth and abundance after introduction of cisco into Lake Opeongo, Ontario. Transactions of the American Fisheries Society 119: 718–729.

McCormick, J.H., B.R. Jones, and R.F. Syrett, 1971. Temperature requirements for growth and survival of larval ciscos (*Coregonus artedii*). Journal of the Fisheries Board of Canada 28: 924-927.

Miller, L.M., J.L. Cruise, N. Niezgocki, J. Prell, and P.C. Jacobson, 2021. Cisco population genetic structure in Minnesota. Investigational Report #570, MNDNR, St. Paul, MN.

Minnesota Department of Conservation, 1967. Minnesota's trout program. Minnesota Department of Conservation, Division of Game and Fish, Section of Fisheries.

MNDNR, 2017. Manual of instructions for lake survey. Special Publication. Minnesota Department of Natural Resources, St. Paul, MN.

Molot, L.A., P.J. Dillon, B.J. Clark and B.P. Neary, 1992. Predicting end-of-summer oxygen profiles in stratified lakes. Canadian Journal of Fisheries and Aquatic Sciences 49(11): 2363-2372.

MPCA, 1987. Summary of fisheries and water quality data pertaining to the proposed ORVW lake trout lakes. Exhibit 95.

MPCA, 2024a. Guidance for assessing the quality of Minnesota surface waters for determination of impairment: 305(b) Report & 303(d) Impaired Waters List: 2024 Assessment and Listing Cycle, St. Paul, MN. 194 pp. https://www.pca.state.mn.us/sites/default/files/wq-iw1-04m.pdf

MPCA, 2024b. Development of eutrophication standards for northern lakes in Minnesota. St. Paul, MN.

MPCA, 2024c. Development of a tiered aquatic life use framework for Minnesota lakes based on fish index of biotic integrity scores and thresholds. St. Paul, MN.

Müller, B., L.D. Bryant, A. Matzinger, and A. Wüest, 2012. Hypolimnetic oxygen depletion in eutrophic lakes. Environmental Science & Technology 46: 9964–9971.

Novakowski, N., 1955. The ecology of Reindeer Lake with special reference to fish. Unpublished Thesis Department Biology. University of Saskatchewan. [Cited in Martin and Oliver (1980)]

O'Connor, D., D. Rottiers, and W. Berlin, 1981. Food consumption, growth rate, conversion efficiency, and proximate composition of yearling lake trout. Administrative Report 81-5. Great Lakes Fisheries Laboratory, Ann Arbor, MI

Opuszynski, K., 1974. Selected temperatures of whitefish, *Coregonus clupeaformis* (Mitchell), in the vertical gradient tank. Roczniki Nauk Rolniczych 96: 63-72. [Cited in Spotila (1979)]

Pace, M.L., J.J. Cole, S.R. Carpenter, J.F. Kitchell, J.R. Hodgson, M.C. Van de Bogert, D.L. Bade, E.S. Kritzberg, and D. Bastviken, 2004. Whole-lake carbon-13 additions reveal terrestrial support of aquatic food webs. Nature 427: 240–243.

Paterson, R., 1968. The lake trout (*Salvelinus namaycush*) of Swan Lake, Alberta. Fisheries Section, Research Report. Alberta Department of Lands and Forests. Fish and Wildlife Division. [Cited in Martin and Oliver (1980)]

Peterson, R., A. Sutterlin, and J. Metcalfe, 1979. Temperature preference of several species of *Salmo* and *Salvelinus* and some of their hybrids. Journal of the Fisheries Board of Canada 36: 1137-1140.

Plumb, J.M. and P.J. Blanchfield, 2009. Performance of temperature and dissolved oxygen criteria to predict habitat use by lake trout (*Salvelinus namaycush*). Canadian Journal of Fisheries and Aquatic Sciences 66: 2011-2023.

Qadri, S., 1961. Food and distribution of lake whitefish in Lac la Ronge, Saskatchewan. Transactions of the American Fisheries Society 90: 303-307.

R Core Team, 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rawson, D., 1961. The lake trout of Lac la Ronge, Saskatchewan. Journal of the Fisheries Board of Canada 18: 423-462.

Reckahn, J.A. 1970. Ecology of young lake whitefish (*Coregonus clupeaformis*) in South Bay, Manitoulin Island, Lake Huron. In Lindsay, C.C. and C.S. Woods (Eds.), Biology of coregonid fishes. University of Manitoba Press, Winnipeg, Manitoba, pp. 437-460. [Cited in Coutant (1977)]

Robin, X., N. Turck, A. Hainard, N. Tiberti, F. Lisacek, J. Sanchez, and M. Müller, 2011. pROC: an open-source package for R and S+ to analyze and compare ROC curves. BMC Bioinformatics, 12, p. 77.

Ryan, P.A. and T.R. Marshall, 1994. A niche definition for lake trout (*Salvelinus namaycush*) and its use to identify populations at risk. Canadian Journal of Fisheries and Aquatic Sciences 51(11): 2513-2519.

Seguin, L.R., 1957. Scientific fish culture in Quebec since 1945. Transactions of the American Fisheries Society 86: 136-143.

Sellers, T.J., B.R. Parker, D.W. Schindler, and W.M. Tonn, 1998. Pelagic distribution of lake trout (*Salvelinus namaycush*) in small Canadian Shield lakes with respect to temperature, dissolved oxygen, and light. Canadian Journal of Fisheries and Aquatic Sciences 55: 170-179.

Sharma, S., M.J. Vander Zanden, J.J. Magnuson, and J. Lyons, 2011. Comparing climate change and species invasions as drivers of coldwater fish population extirpations. PLoS One 6: e22906.

Siesennop, G.D., 1998. Evaluation of lake trout index netting methods in ten northeastern Minnesota lakes. Minnesota Department of Natural Resources Investigational Report 461

Siesennop, G.D., 1998. Growth of lake trout captured during spring, summer, and fall index gill netting in 10 northeastern Minnesota lakes. Minnesota Department of Natural Resources Investigational Report 469.

Siesennop, G.D., 2000. Estimating potential yield and harvest of lake trout (*Salvelinus namaycush*) in Minnesota's lake trout lakes, exclusive of Lake Superior. Minnesota Department of Natural Resources Investigational Report 487.

Snucins, E. and J. Gunn, 1995. Coping with a warm environment: behavioral thermoregulation by lake trout. Transactions of the American Fisheries Society 124: 118-123.

Spotila, J.R., K.M. Terpin, R.R. Koons, and R.L. Bonati, 1979. Temperature requirements of fishes from eastern Lake Erie and the upper Niagara River: a review of the literature. Environmental Biology of Fishes 4: 281-307.

State of Michigan, 2006. Part 4. Water quality standards. January 13, 2006.

State of Minnesota, 2018. State Register, 30 April 2018. Volume 42, Number 44. pp. 1298-1341 (42 SR 1298).

State of Minnesota, 2024. State Register, 15 July 2024. Volume 49, Number 3. p. 45 (49 SR 45).

Stefan, H.G., M. Hondzo, X. Fang, J.G. Eaton, and J.H. McCormick, 1996. Simulated long term temperature and dissolved oxygen characteristics of lakes in the north-central United States and associated fish habitat limits. Limnology and Oceanography 41(5): 1124-1135.

Stefan, H.G., X. Fang, and M. Hondzo, 1998. Simulated climate change effects on year-round water temperatures in temperate zone lakes. Climatic change 40(3): 547-576.

Stefan, H.G., X. Fang, and J.G. Eaton, 2001. Simulated fish habitat changes in North American lakes in response to projected climate warming. Transactions of the American Fisheries Society 130(3): 459-477.

Straight, W.J. 1969. Depth distribution of splake of known ability to retain swimbladder gas. M. Sc. Thesis, York University, Toronto, Ontario. [Cited in Martin and Oliver (1980)]

Trippel, E.A. and Beamish, F.W.H., 1989. Lake trout (*Salvelinus namaycush*) growth potential predicted from cisco (*Coregonus artedii*) population structure and conductivity. Canadian Journal of Fisheries and Aquatic Sciences 46(9): 1531-1538.

Tompkins, F.T. and J.M. Fraser, 1950. The preferred temperature of a sample of Great Lakes whitefish (*Coregonus clupeaformis*). Department of Zoology. University of Toronto. [Cited in Christie and Regier (1988) and Ferguson (1958)]

Turgeon, J., S.M. Reid, A. Bourret, T.C. Pratt, J.D. Reist, A.M. Muir, and K.L. Howland, 2016. Morphological and genetic variation in cisco (*Coregonus artedi*) and Shortjaw Cisco (*C. zenithicus*): multiple origins of Shortjaw Cisco in inland lakes require a lake-specific conservation approach. Conservation Genetics 17(1): 45-56.

Vanderbloemen, S.N., J.A. Gorne, G.G. Sass, and S.L. Shaw, 2020. Influence of cisco (*Coregonus artedi*, Lesueur) on muskellunge (*Esox masquinongy*, Mitchill) mean length, population size structure, and maximum size in northern Wisconsin lakes. Journal of Applied Ichthyology 36: 159-167.

Walker Jr, W.W., 1979. Use of hypolimnetic oxygen depletion rate as a trophic state index for lakes. Water Resources Research 15: 1463-1470.

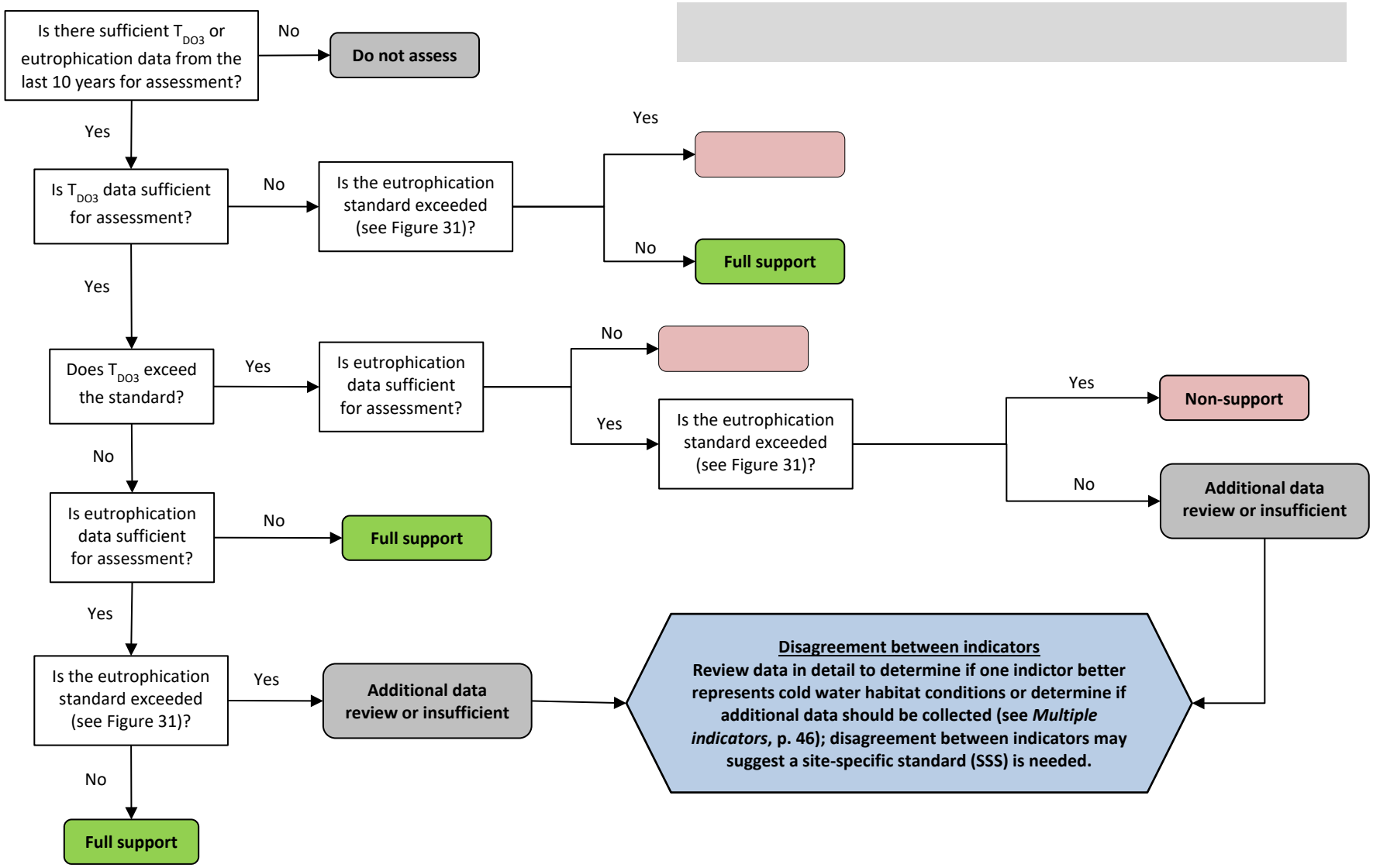
Webster, D.A., W.G. Bentley, and J.P. Galligan, 1959. Management of the lake trout fishery of Cayuga Lake, New York, with special reference to the role of hatchery fish. Memoirs of the Cornell University Agricultural Experiment Station 357: 1-83. [Cited in Martin and Oliver (1980)]

Wood, S.N., 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society (B) 73(1): 3-36.

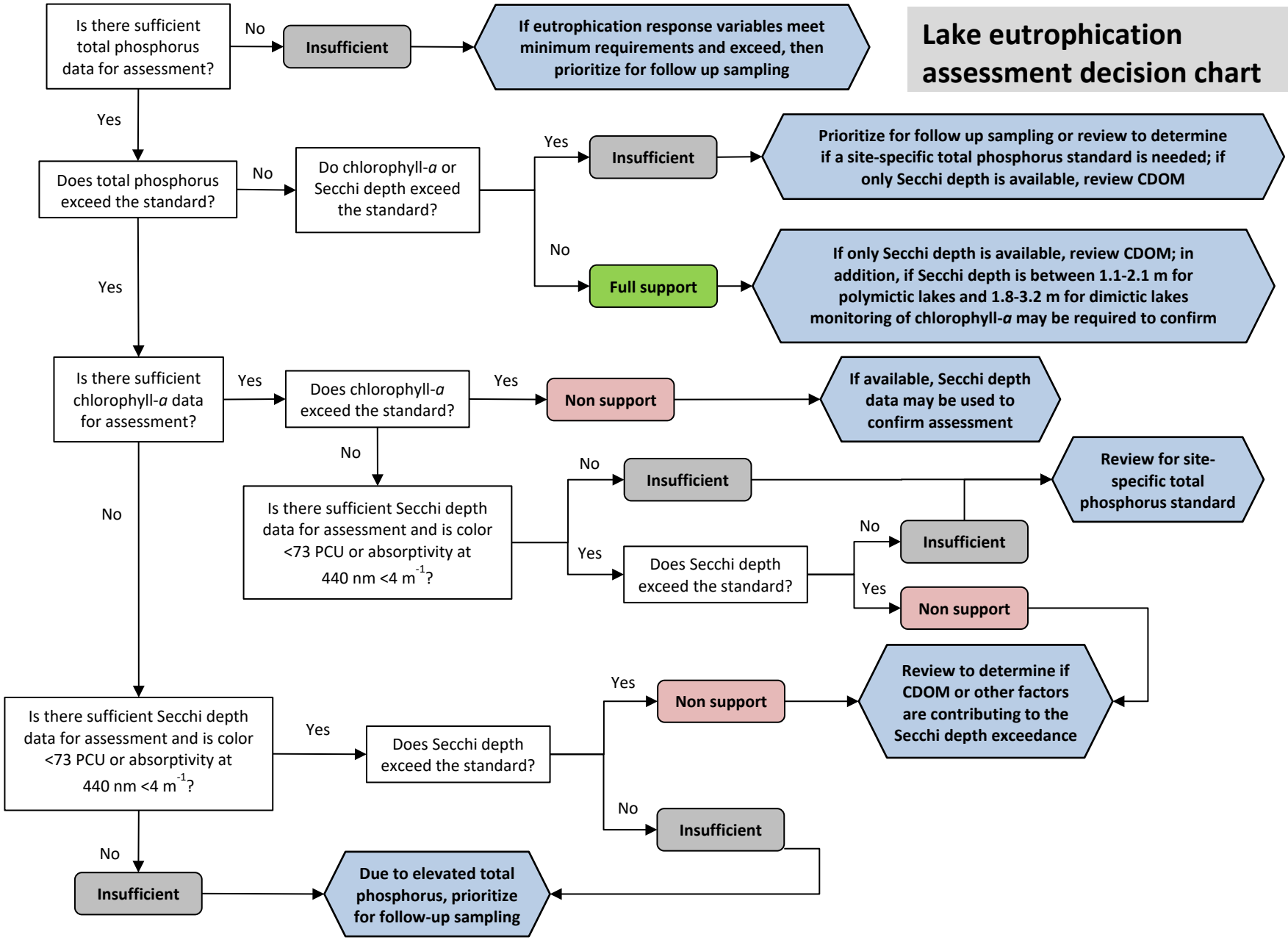
Woodger, C. D., 1976. Morphological variations as induced by environment in coregonids. Environmental Biology of Fishes 1: 101-105.

Woolway, R.I., C.J. Merchant, J. Van Den Hoek, C. Azorin-Molina, P. Nõges, A. Laas, E.B. Mackay, and I.D. Jones, 2019. Northern Hemisphere atmospheric stilling accelerates lake thermal responses to a warming world. Geophysical Research Letters 46(21): 11983-11992.

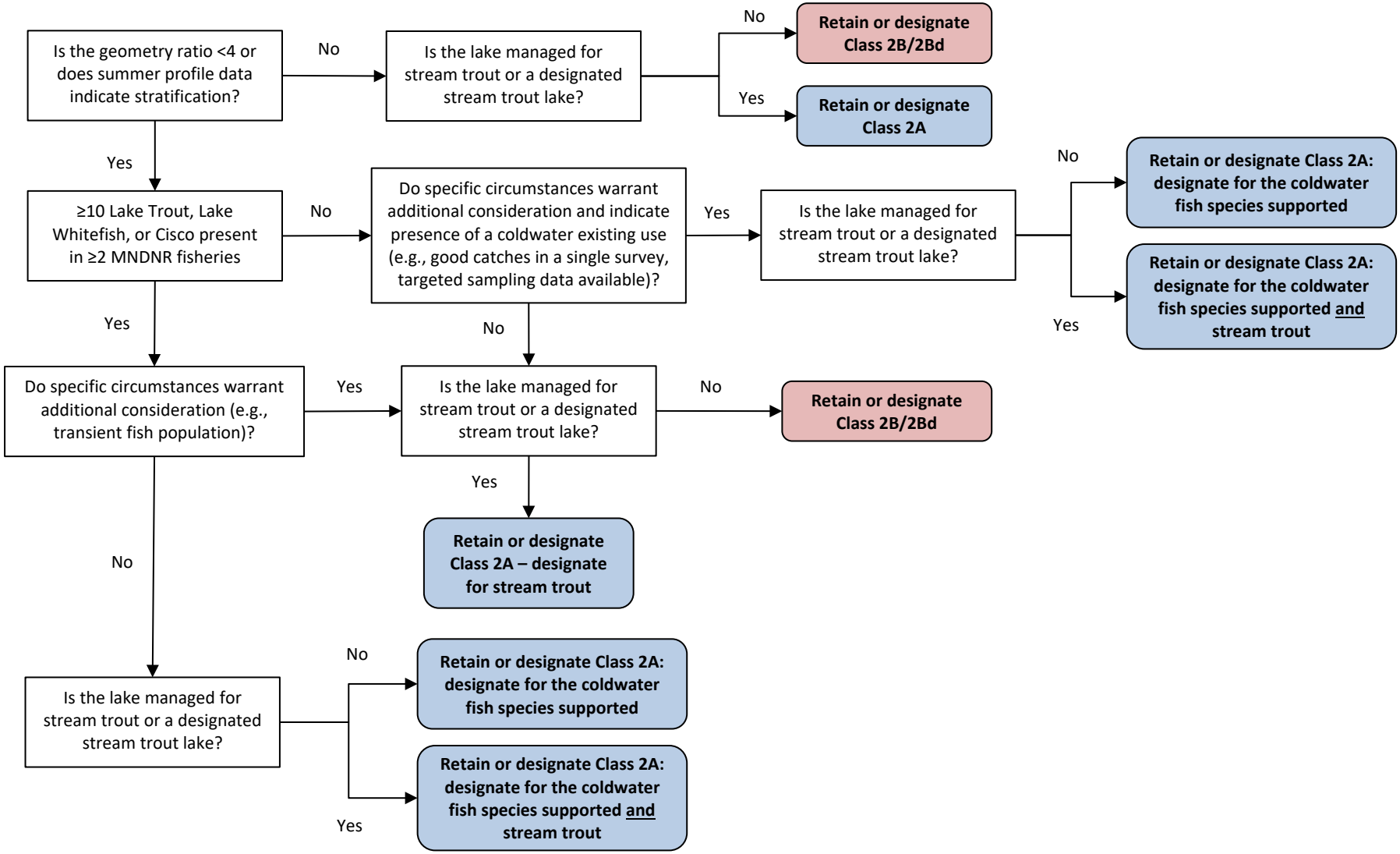
Appendix A: Water quality assessment decision charts



Lake eutrophication assessment decision chart



Appendix B: Coldwater habitat designation decision chart



Appendix C: Coldwater lake use designations

The following provides the specific documentation for the draft coldwater lake use designations and the fish species protected in each lake. The lakes are organized by major watershed and then by subbasin (8-digit Hydrologic Unit Codes [HUC 8]). Within these sections, data supporting the draft use designation and the coldwater fish species protected in each lake is summarized in a table. These tables include information on the coldwater species these lakes support or should support, fisheries survey summaries for these species, geometry ratio, and current and draft use designations. The current and draft aquatic life use designation class (i.e., Class 2A, 2B, or 2Bd) and the coldwater fish species protected (i.e., Lake Trout, Lake Whitefish, Cisco, and stream trout) are provided for each lake. The species codes (i.e., LAT, LKW, TLC, SRT) appear as superscripts or in brackets. The species codes in superscript are the species designations currently assigned to these lakes, but which are not codified in rule (Minn. R. 7050.0470). When the species codes are in brackets, they are the draft coldwater habitat designation and reflect the formatting for Minn. R. 7050.0470 as part of this rule revision. In cases where additional information is required to describe the proposed or confirmed designated use, a more detailed description is provided following the table. Lakes with additional information are largely lakes where the fisheries surveys did not meet the minimum criteria for designation (i.e., number of fish sampled or number of surveys present), but where supplemental information did demonstrate that the lake should be designated for the protection of a coldwater species. This information serves as the technical documentation for these beneficial use designations.

In addition to the coldwater lake designations, the designations in this document include TALU designations. The information supporting these designations is included in the TALU framework rule technical support document (TSD; MPCA 2024c). The TALU designations are included in Appendix C to be comprehensive and to avoid confusion by listing the same draft use designations across documents. The TALU framework includes two tiers which are assigned based on the condition of the warm water fish community: Exceptional and General uses. The General Use is assigned by default to lakes and to lakes where it has been demonstrated that it supports a good fish community. This is determined through a review of fish index of biotic integrity (IBI) scores and supporting information (see MPCA 2024c). General Use lakes are identified by the inclusion of the subclass designator “g” which is added to the Class 2 designation. Exceptional Use lakes are those that have been determined to support excellent fish communities (see MPCA 2024c). Exceptional Use lakes are identified by the inclusion of the subclass designator “e” which is added to the Class 2 designation.

The abbreviations and symbols used in the following section are as follows:

ALU	Aquatic life use
2B	Cool and warm water aquatic life and habitat (Class 2B)
2Bd	Cool and warm water aquatic life and habitat also protected as a source for drinking water (Class 2Bd)
2Be	Exceptional use cool and warm water aquatic life and habitat (Class 2Be)
2Bdg	General use cool and warm water aquatic life and habitat also protected as a source for drinking water (Class 2Bdg)
2Bg	General Use cool and warm water aquatic life and habitat (Class 2Bg)
2A	Coldwater aquatic life and habitat
2Ae	Exceptional use coldwater aquatic life and habitat
2Ag	General use coldwater aquatic life and habitat

GR	Geometry ratio
LAT	Lake Trout (*Salvelinus namaycush*) coldwater habitat
LKW	Lake Whitefish (*Coregonus clupeaformis*) coldwater habitat
NC	No change
SC	Species change
SM	Species modification
SRT	stream trout coldwater habitat
TLC	Cisco/Tullibee/Lake Herring (*Coregonus artedi*) coldwater habitat

Table field descriptions

Lake name: The lake name as it appears in the MPCA waterbody unit database. Different names may also be assigned to a lake and where possible additional lake names are provided in parentheses.

WID: Lakes are assigned a Waterbody identification or WID code, which is used to identify assessment units and track assessment efforts. WIDs are also used to assign and track designated uses. For lakes, the code follows MNDNR conventions, where the first two numbers refer to the county number (alphabetical), the middle four numbers are a random, unique lake number, and the final two digits are the embayment (basin) number. The MPCA includes dashes between the county number, lake number, and bay number and the MNDNR does not include dashes. The MPCA's convention for WID numbers is followed in this report.

In some cases, multiple basins are listed because these separate basins may be used by the MPCA to organize data collection and for water quality assessments. In addition, there may be some lakes listed in this rule where not every bay is included in the designation. This is because some of the bays were determined to be shallow and unlikely to support coldwater fishes even though other portions of the lake are suitable. This was done to align with the MPCA's assessment process and to help ensure that data used for assessments is not from these shallow bays. However, the MNDNR does not divide lakes into bays for management purposes.

Geometry ratio (GR): Geometry ratio is a measure of lake depth relative to lake size and provides an estimate of mixing status. Geometry ratio is calculated as: $A_0^{0.25}/z_{max}$, where A_0 is lake surface area (m^2) and z_{max} is maximum depth (m) (Stefan et al. 1996). Lakes with a geometry ratio of less than 4 tend to be dimictic whiles lakes with a geometry ratio of more than 4 are polymictic (see Figure 4).

Fisheries survey summary: An abbreviated summary of fisheries survey information is provided for Cisco, Lake Whitefish, Lake Trout, and stream trout. The summaries for Cisco, Lake Whitefish, and Lake Trout differ from stream trout because the former are largely native populations whereas stream trout in lakes are typically highly managed and not sustainable without stocking. The information provided is largely derived from the Fishes of Minnesota Mapper (https://maps2.dnr.state.mn.us/ewr/fom/mapper.html) and much of this information can also be found on the MNDNR's Lake Finder (https://www.dnr.state.mn.us/lakefind/index.html). The fisheries survey summaries are coupled with information regarding the MNDNR's assessment of the current status of the population or management of the coldwater fishes present. See ***Fisheries surveys*** (p. 52) for additional description of the use of fisheries survey data for determining the status of coldwater fish populations.

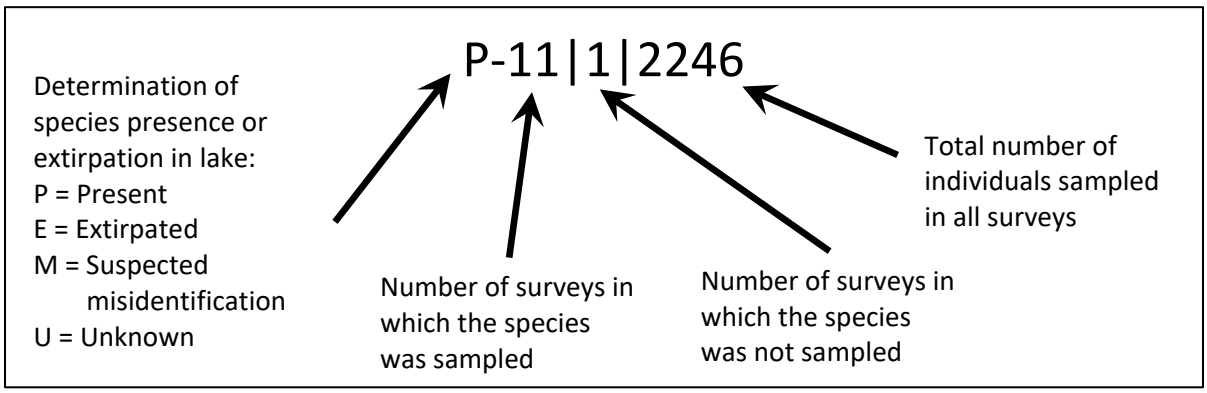
Cisco, Lake Whitefish, and Lake Trout survey summaries (Figure 28): This summary includes a determination of whether the species' current status in a lake is present (P), extirpated (E), suspected

misidentification (M), or unknown (U). The fisheries evaluation is based on the most recent surveys and is a best determination of the status of the species. Descriptions of species' population status categories are as follows:

- **Present (P):** The species has been observed in the most recent gill net surveys or by other means (e.g., vertical gill net survey) within last decade (2010-2020).
- **Extirpated (E):** The population of coldwater fish species has been extirpated or the lake has a declining trend in catches with no recent observations. The extirpation flag can indicate that a native population of a coldwater fish was extirpated; however, in most cases the extirpation flag indicates that a stocked population is no longer extant due to the cessation of stocking. For these coldwater fish species, the cessation of stocking was typically due to a failure to establish as a self-sustaining population or poor returns from the stocking. The extirpation flag may also indicate that a species was sampled infrequently due to the species being transient from connected lakes, but it is not considered to be a native, self-sustaining population.
- **Suspected misidentification (M):** Records of the presence of a species in a lake are likely incorrect due to misidentification. Identification errors of Cisco and Lake Whitefish sometimes occur and although vouchers are often not present, other evidence can be used to determine if identifications are suspected to be incorrect.
- **Unknown (U):** Indicates that that the species has been observed but is not present in most recent gill net survey or within last decade (2010-2020). In cases where recent surveys are lacking or the survey information is inconclusive, the species' status is left as unknown.

The summary also provides the number of surveys in which the species was sampled and the number of surveys in which it was not sampled. Finally, the summary includes the total number of individuals of a species collected in all surveys. An example of this summary is provided below with an explanation of each element.

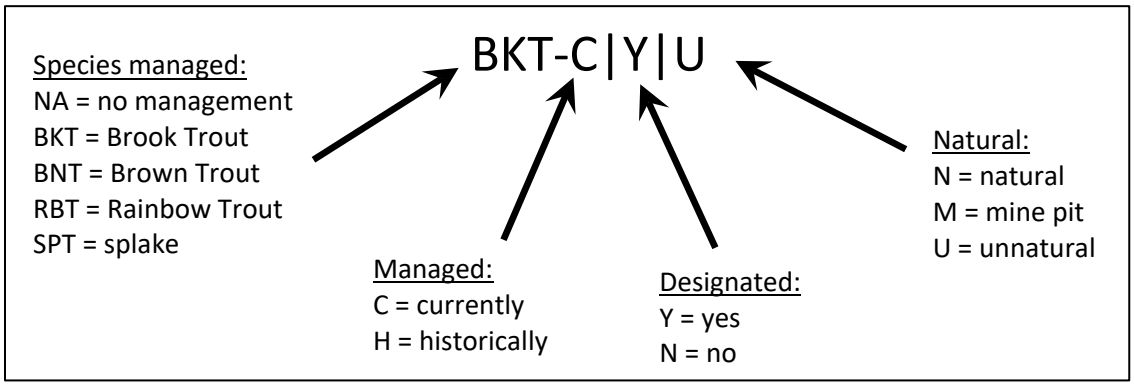
Figure 28. Example of Lake Trout, Lake Whitefish, and Cisco fisheries survey information.



Stream trout survey summaries (Figure 29): Stream trout summaries include a list of the stream trout species managed in the lake and if trout are currently managed in the lake. Lakes which are not currently managed for stream trout are listed as having "no management (NA)." In the next field, management status is indicated. Currently managed lakes are those which are currently stocked on a regular basis whereas historically managed lakes are no longer stocked regularly. Historically managed lakes may be removed from the MNDNR's list of designated trout lakes or stocking may resume in the in the future. The designation flag indicates whether the lake is currently a designated trout lake on the MNDNR's trout lakes list (Minn. R. 6264.0050). Finally, the lake type and fish population origin are provided in the last code. "Natural" lakes are those with at some natural recruitment of stream trout

from connected stream habitats whereas stream trout are only maintained in “unnatural” lakes through stocking. Populations of stream trout in “mine pits” are also maintained only through stocking.

Figure 29. Example of stream trout fisheries survey information.



Current ALU: Current aquatic life use (ALU) assigned to the lake. When a coldwater fish species is protected by the current ALU designation this is indicated by superscript code (LAT = Lake Trout or SRT = stream trout).

Draft ALU: The draft ALU with additional annotation for coldwater lakes to indicate the species protected in each lake. This includes the thermal classification (i.e., coldwater versus warm/cool water) and the proposed TALU designation.

Trout lake: This field indicates whether the lake is designated by the MNDNR as a trout lake in Minn. R. 6264.0050, subp. 2. These lakes are largely managed for stream trout although other coldwater species may be present. Lakes that the MNDNR manages for Lake Trout are not designated trout lakes unless they are also managed for stream trout. In addition, some lakes that are managed for stream trout are not designated trout lakes.

Designation type (Type): There are four use designation types in this rule revision This field codes for these four types: 1) Species confirmation (SC): confirmation of coldwater species protected by the current Class 2A designation, 2) Species modification (SM): modification of the coldwater fish species protected by the current Class 2A designation, 3) 2A designation (2A): designation from Class 2B/2Bd to Class 2A and confirmation of the coldwater fish species protected by the draft Class 2A designation, 4) 2Bd designation (2Bd): designation from Class 2A to Class 2Bd based on a use attainability analysis (UAA), and 5) No change (NC): after review it was determined that the current use designation is appropriate.

1. Lake Superior basin

a. Lake Superior – North watershed (04010101)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 18 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lake Superior – North watershed (04010101).

Table 18. List of draft Class 2A use confirmations and designations for lakes in the Lake Superior – North watershed (04010101) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Alder*	16-0114-00	1.79	P-11|0|61				$2A^{LAT}$	2Ag[LAT]	No	SC
Alton*	16-0622-00	2.03	E-4|8|7		P-11|1|2246		$2A^{LAT}$	2Ag[TLC]	No	SM
Bath	16-0164-00	2.61				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bearskin	16-0228-00	1.58	P-10|1|272				$2A^{LAT}$	2Ag[LAT]	No	SC
Bearskin, East*	16-0146-00	1.93	P-8|9|54				$2A^{LAT}$	2Ag[LAT]	No	SC
Bench*	16-0063-00	3.36				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Benson	38-0018-00	1.87				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Birch	16-0247-00	1.49	P-11|1|117			RBT-C|N|U	$2A^{LAT}$	2Ag[LAT,SRT]	No	SM
Bogus (Patty's)	16-0050-00	2.17				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bone (Long)	38-0065-00	1.30	E-4|11|19			RBT, SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Boys (Kimball)	16-0044-00	4.45				BKT-C|Y|N	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Brule*	16-0348-00	3.51	E-2|10|15		P-12|0|1379		$2A^{LAT}$	2Ag[TLC]	No	SM
Caribou*	16-0141-00	2.13	E-0|5|0	U-5|0|1823			2Bd	2Ag[LKW]	No	2A
Carrot	16-0071-00	4.10				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Chester	16-0033-00	1.98	E-1|19|4			BNT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Clearwater*	16-0139-00	1.22	P-19|0|668		P-19|0|2977		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Crosscut	38-0257-00	3.47				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Crystal*	16-0090-00	1.09	P-6|0|63				2A^{LAT}	2Ag[LAT]	No	SC
Daniels*	16-0150-00	1.38	P-14|0|468				2A^{LAT}	2Ag[LAT]	No	SC
Davis*	16-0435-00	1.73	U-1|1|2				2A^{LAT}	2Ag[LAT]	No	SC
Deer*	16-0136-00	2.50		U-3|0|56			2Bd	2Ag[LKW]	No	2A
Devil Track	16-0143-00	3.42		P-14|5|88			2B	2Ag[LKW]	No	2A
Divide (Towhey)	38-0256-00	3.33				RBT, SPT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Duke	16-0111-00	5.14				BKT-C|Y|N	2A^{SRT}	2Ag[SRT]	Yes	SC
Duncan*	16-0232-00	1.05	P-9|0|115		U-8|1|1097		2A^{LAT}	2Ag[LAT,TLC]	No	SM
Dunn*	16-0245-00	1.28	P-7|0|191				2A^{LAT}	2Ag[LAT]	No	SC
East	38-0020-00	4.12				NA-H|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Echo	38-0028-00	1.09	E-5|6|31			RBT, SPT-C|Y|U	2A^{LAT,SRT}	2Ag[SRT]	Yes	SM
Esther	16-0023-00	2.25	E-5|5|7			SPT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Feather	16-0905-00	1.87				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Flour	16-0147-00	1.49	P-6|12|48		P-18|0|2538		2A^{LAT}	2Ag[LAT,TLC]	No	SM
Gadwell (Gadwall)*	16-0060-00	1.07				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Gaskin*	16-0319-00	1.93	U-0|2|0	P-2|0|28	U-1|1|27		2A^{LAT}	2Ag[LAT,LKW,TLC]	No	SM
Gogebic (Duck)*	16-0087-00	1.21				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Goldeneye (Duck)	38-0029-00	2.46				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Greenwood	16-0077-00	1.74	P-20|0|515	U-12|8|86	P-20|0|3180		2A^{LAT}	2Ag[LAT,LKW,TLC]	No	SM
Jim	16-0135-00	2.90	U-5|1|16				2A^{LAT}	2Ag[LAT]	No	SC
Junco	16-0159-00	14.1				BKT-C|Y|N	2A^{SRT}	2Ag[SRT]	Yes	SC
Kemo	16-0188-00	1.43	P-15|0|285				2A^{LAT}	2Ag[LAT]	No	SC
Kimball	16-0045-00	4.88				BNT, RBT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Leo	16-0198-00	2.97				RBT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Lima	16-0226-00	1.87				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Little Trout*	16-0170-00	1.75	P-5|0|168				2A^{LAT}	2Ag[LAT]	No	SC
Loft	16-0031-00	1.06				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Margaret	16-0896-00	1.42				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
McFarland	16-0027-00	2.37	U-0|9|0	P-9|0|111	P-8|1|27		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM
Mink	16-0046-00	4.78				RBT, SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Misquah*	16-0225-00	1.15	P-7|1|17				$2A^{LAT}$	2Ag[LAT]	No	SC
Moose*	16-0043-00	1.08	U-4|0|54	U-4|0|315	U-3|1|108		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Moosehorn	16-0015-00	7.30				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Moss	16-0234-00	1.16	P-15|0|589	E-1|14|2	E-1|14|55		$2A^{LAT}$	2Ag[LAT]	No	SC
Mountain*	16-0093-00	0.71	P-8|0|852				$2A^{LAT}$	2Ag[LAT]	No	SC
Muckwa	16-0105-00	3.48				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Musquash	16-0104-00	3.41	E-1|10|21			SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
North Shady	16-0076-00	3.09				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Olga	16-0024-00	1.09	E-2|7|2			SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Olson	16-0158-00	3.49				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Pancore (Lost)	16-0475-00	1.60				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Partridge*	16-0233-00	1.05	P-7|0|279				$2A^{LAT}$	2Ag[LAT]	No	SC
Pemmican*	16-0085-00	1.18				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Pierz*	16-0091-00	2.86	U-0|8|0			SPT-C|N|U	2Bd	2Ag[SRT]	No	2A
Pike	16-0252-00	3.49		P-17|2|346			2B	2Ag[LKW]	No	2A
Pike, East*	16-0042-00	2.53		U-6|0|538	U-6|0|436		2Bd	2Ag[LKW,TLC]	No	2A
Pike, West*	16-0086-00	1.16	U-6|0|270		U-5|1|53		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Pine*	16-0041-00	1.57	P-8|3|31	P-10|1|1756	P-6|5|143		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Pine	16-0194-00	2.40	E-5|16|17			RBT, SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Pine Mountain	16-0108-00	2.79				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Poplar	16-0239-00	1.88	E-3|23|19	P-23|3|250	E-3|23|29		2Bd	2Ag[LKW]	No	2A
Ram*	16-0174-00	1.88	P-12|2|180			RBT-C|Y|U	$2A^{LAT,SRT}$	2Ag[LAT,SRT]	Yes	SC
Rose*	16-0230-00	1.46	U-3|0|26	U-3|0|155	U-3|0|82		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Shoe	16-0080-00	5.76				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Sock*	16-0335-00	2.42				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Sonju	38-0248-00	8.13				BKT-C|Y|N	2A^{SRT}	2Ag[SRT]	Yes	SC
South*	16-0244-00	0.95	U-2|0|91		U-2|0|12		2A^{LAT}	2Ag[LAT,TLC]	No	SM
State*	16-0293-00	1.43	U-0|0|0				2A^{LAT}	2Ag[LAT]	No	SC
Steer	38-0920-00	1.58				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Superior	16-0001-00	-	-	-	-	-	2A	2Ag[LAT,LKW,TLC, SRT]	No	SM
Swan*	16-0268-00	0.98	U-0|4|0	P-4|0|248			2A^{LAT}	2Ag[LKW]	No	SM
Talus	16-0187-00	2.13				RBT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Thompson	16-0160-00	4.37				BNT, RBT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Thrasher	16-0192-00	2.10	E-1|7|1			SPT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Thrush	16-0191-00	1.05	E-5|1|30			BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Tom	16-0019-00	3.36		P-11|4|173			2B	2Ag[LKW]	No	2A
Topper (Sound, Round)*	16-0336-00	2.45				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Trout	16-0049-00	1.36	P-15|0|344		E-9|6|84	RBT-C|N|U	2A^{LAT}	2Ag[LAT,TLC,SRT]	No	SM
Turnip	16-0132-00	2.24				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Unnamed	16-0903-00	1.21	E-0|1|0			BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Unnamed	16-0908-00	-				SPT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Vale*	16-0061-00	1.68				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Vernon*	16-0267-00	1.02	U-1|4|2	U-5|0|474	U-1|4|1		2Bd	2Ag[LKW]	No	2A
Weasel (Sled)	16-0897-00	2.07				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Wee*	16-0483-00	1.41				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Wench*	16-0398-00	0.98				BKT-C|Y|U	2A^{SRT}	2Ag[SRT]	Yes	SC
Winchell*	16-0354-00	1.18	P-4|0|90	P-3|1|3	P-4|0|609		2A^{LAT}	2Ag[LAT,TLC]	No	SM

*** Partially or fully within the Boundary Waters Canoe Area Wilderness.**

Alton Lake (16-0622-00): The current Class 2A designation for Alton Lake was assigned to protect Lake Trout. It is listed as an "inland Lake Trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "marginal." Lake Trout are not native to Alton Lake but were historically stocked. Lake Trout in this lake have been determined to not be sustainable and this species is no longer stocked. The poor survival of Lake Trout in this lake may be attributed to marginal dissolved oxygen conditions. As a result, Alton Lake will not be designated for the protection Lake Trout. However, Alton Lake supports a natural population of Cisco. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Birch Lake (16-0247-00): The current Class 2A designation for Birch Lake was assigned to protect Lake Trout and it is listed as a "potential inland Lake Trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not considered native to this lake, but stocking has resulted in a small, self-sustaining population of Lake Trout. Rainbow Trout are also stocked in Birch Lake, but it is not designated a trout lake by the MNDNR. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout and stream trout (Class 2Ag [LAT,SRT]).

Bone Lake (38-0065-00): Bone Lake is currently designated Class 2A to protect stream trout. Lake Trout were stocked from 1915-1985 but are not native to Bone Lake. Stocking was discontinued and the introduced population was not self-sustaining. As a result, it is not appropriate to assign protections for Lake Trout in Bone Lake. However, the lake is currently a MNDNR designated trout lake (Minn. R. 6264.0050) and is managed for Rainbow Trout. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Brule Lake (16-0348-00): The Class 2A designation for Brule Lake was assigned to protect Lake Trout. It is listed as an "inland Lake Trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has an "adverse fish population." Lake Trout are possibly native to this lake, but there has also been stocking of Lake Trout in Brule Lake. Stocking efforts in the 1930s-1970s to establish a population were unsuccessful and Lake Trout have been determined to not be sustainable in this lake. As a result, Brule Lake will not be designated for the protection Lake Trout because this is not an existing use. However, Brule Lake supports a natural population of Cisco. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Caribou Lake (16-0141-00): Caribou Lake is in the BWCAW and is currently designated Class 2Bd. It is unknown if Lake Trout were native to the lake, but trout were stocked in 1970. No Lake Trout were detected in the 5 fisheries surveys for the lake. As a result, Caribou Lake will not be designated for the protection Lake Trout. However, Caribou Lake supports a natural population of Lake Whitefish. Considering this information, it is reasonable to designate Caribou Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

Chester Lake (16-0033-00): Chester Lake is currently designated to protect stream trout and it is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). This report also notes that this lake was reclaimed in 1965 and stocked with Ohrid trout (*Salmo letnica*).

Lake Trout are not native to Chester Lake and are not currently stocked. However, Chester Lake is currently designated a trout lake by the MNDNR (Minn. R. 6264.0050) and is managed for Brown Trout. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). The WID number for this lake is incorrect in Minn. R. 7050.0470. It is listed as "69-0033-00," but it should be "16-0033-00." This error will be corrected as part of this revision. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Davis Lake (16-0435-00): Davis Lake is currently designated to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Davis Lake is in the BWCAW and there is limited data on the fishery in this lake. Whether or not Lake Trout are native or if a population is currently extant in this lake is unknown. Two Lake Trout were collected in 1999 and at least one was from a previous stocking. Additional data is needed to confirm if a Lake Trout population has been established in Davis Lake. As a result, Davis Lake will retain the designation for the protection Lake Trout, but additional work may demonstrate that Lake Trout habitat is not an existing use. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout (Class 2Ag [LAT]).

East Lake (38-0020-00): East Lake is currently designated Class 2A to protect stream trout. Management of stream trout in East Lake was discontinued although the lake is still a MNDNR designated trout lake (Minn. R. 6264.0050). This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Echo Lake (38-0028-00): Echo Lake is currently designated to protect stream trout and Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout were stocked from 1919-1985 but are not native to Echo Lake. Stocking was discontinued and the introduced population was not self-sustaining. As a result, it is not appropriate to retain protections for Lake Trout in Echo Lake. However, the lake is currently a MNDNR designated trout lake (Minn. R. 6264.0050) and is managed for Rainbow Trout and splake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). This lake is currently designated as a Lake Trout lake and is outside the BWCAW. As a result, the removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) for Echo Lake.

Esther Lake (16-0023-00): Esther Lake is currently designated to protect stream trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not native to Esther Lake and were stocked in 1954, 1965, 1970, and 1973. Stocking was discontinued and the introduced population was not self-sustaining. As a result, it is not appropriate to assign protections for Lake Trout to this lake. However, the lake is currently a MNDNR designated trout lake (Minn. R. 6264.0050) and is managed for splake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Gaskin Lake (16-0319-00): The current Class 2A designation for Gaskin Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that it has "good" dissolved oxygen conditions. Lake Trout are considered native to this lake, but their current status is unknown. Two MNDNR fisheries surveys for Gaskin Lake (1990 and 2012) found no Lake Trout, but anglers have reported catching the species. As a result, Gaskin Lake will retain the designation for the protection Lake Trout, but additional work may demonstrate

that Lake Trout habitat is not an existing use. Gaskin Lake does support natural populations of Cisco and Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Lake Whitefish, and Cisco (Class 2Ag [LAT,LKW,TLC]).

McFarland Lake (16-0027-00): The Class 2A designation for McFarland Lake was assigned to protect stream trout, but it is not currently managed for stream trout. It is listed as a "potential inland Lake Trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has an "adverse fish population." Comments from a 1987 MPCA rulemaking exhibit (MPCA 1987) indicate that Lake Trout were periodically stocked in this lake from the early 1940's until 1967, but there is no record of Lake Trout being captured. The MNDNR has conducted 6 fisheries surveys since 1985 and none have sampled trout. A study of the temperature-oxygen profile in this lake found no areas capable of supporting Lake Trout. Since efforts to stock and establish a population were unsuccessful and conditions are unsuitable to support Lake Trout, McFarland Lake will be designated for the protection Lake Trout. However, McFarland Lake supports natural populations of Cisco and Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [TLC,LKW]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Pierz Lake (16-0091-00): Pierz Lake is currently designated Class 2Bd and is not designated for the protection of any coldwater fish species. The status of a possible Lake Trout population in Pierz Lake is unknown. A single Lake Trout was sampled in 1956, but no additional fish have been sampled in subsequent surveys. At this time, it not appropriate to assign protections for Lake Trout in this lake, but additional monitoring could determine that a population is present and this designation is needed. Although the lake is not currently a designated trout lake, it is managed for splake. Considering this information, it is reasonable to designate Pierz Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Poplar Lake (16-0239-00): Poplar Lake is currently designated Class 2Bd. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has an "adverse fish population" and "marginal" dissolved oxygen. The MNDNR stocked Lake Trout in 1926 and 1997-2005, but fisheries surveys likely only sampled stocked fish. This indicated that a self-sustaining population was not established and stocking was stopped. Lake Trout are considered native to the lake, but no surveys have collected fish that were the result of natural reproduction. As a result, Poplar Lake will not be designated for the protection Lake Trout. Cisco were stocked in Poplar Lake in the 1930s, but this species was last recorded in 1959. Poplar Lake does support a natural population of Lake Whitefish. Considering this information, it is reasonable to designate Poplar Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

State Lake (16-0293-00): State Lake is currently designated Class 2A for the protection of Lake Trout. The status of a Lake Trout population in State Lake is unknown. MNDNR surveys have not sampled any Lake Trout, but there are angler reports of Lake Trout in this lake. Minnesota Department of Conservation (1967) listed this as a "potential inland Lake Trout lake" and indicated good dissolved oxygen and temperature conditions in the lake. As a result, State Lake will retain the designation for the protection of Lake Trout, but additional work may demonstrate Lake Trout habitat is not an existing use. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout (Class 2Ag [LAT]).

Swan Lake (16-0268-00): The current Class 2A designation for Swan Lake was assigned to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has "good" dissolved oxygen and temperature conditions. Lake Trout are thought to be possibly native to this lake, but there is no record of an extant population of Lake Trout. MNDNR fisheries surveys for Swan Lake from 1973-2014 have not sampled any Lake Trout despite stockings in the 1990s. As a result, it is not appropriate to retain the designation for protection of Lake Trout. Swan Lake does support a natural population Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Thrush Lake (16-0191-00): The current Class 2A designation for Thrush Lake was assigned to protect stream trout. Although not native, Lake Trout were stocked in 1973. Stocking was discontinued and the introduced population was not self-sustaining. As a result, it is not appropriate to assign protections for Lake Trout in this lake. However, the lake is currently designated a trout lake by the MNDNR (Minn. R. 6264.0050) and is managed for Brook Trout. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Trout Lake (16-0049-00): The current Class 2A designation of Trout Lake was assigned to protect Lake Trout. Lake Trout are not currently stocked in this lake, but Lake Trout have been determined to be sustainable with natural recruitment. As a result, Trout Lake should be managed to protect Lake Trout. Trout Lake supported a natural population of Cisco. In 17 MNDNR surveys (1951-1999), Cisco were collected in 9 surveys with a total of 84 individuals sampled. Cisco have not been collected from this lake since 1999 and were likely extirpated due to the introduction of Rainbow Smelt. Although Cisco are extirpated, a population was present after November 28, 1975, demonstrating that protection of Cisco is an existing use. In addition, Trout Lake is also managed for Rainbow Trout. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Cisco, and stream trout (Class 2Ag [LAT,TLC,SRT]).

Vernon Lake (16-0267-00): Vernon Lake is currently designated Class 2Bd. Lake Trout are considered to be native in Vernon Lake and an effort to reintroduce the species took place in the 1990s. There was carry over observed from these stockings, but no natural recruitment was documented. The presence of Lake Trout in this lake is unlikely and additional surveys would be needed to establish if a Lake Trout population is present in Vernon Lake. As a result, Vernon Lake will not be designated for the protection of Lake Trout at this time. However, based on fisheries surveys, Vernon Lake supports a large population of Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Wee Lake (16-0483-00): The WID number for Wee Lake listed in Minn. R. 7050.0470 is incorrect. This lake is currently listed as 16-0183-00 in rule and as part of this rule revision the WID number will be corrected to 16-0483-00.

Class 2Bd designations

The following lakes will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the use designation is provided in Table 19 and additional details are provided following the table. For these lakes, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering the information below, it is reasonable to assign Class 2Bdg to these lakes for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lake Superior – North watershed (04010101).

Table 19: List of draft Class 2Bd use designations for lakes in the Lake Superior – North watershed (04010101) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout water	Type
Cone, Upper*	16-0412-00	1.40					$2A^{SRT}$	2Bdg	No	2Bd
Devilfish	16-0029-00	2.90	E-3|10|79				$2A^{SRT}$	2Bdg	No	2Bd
Hungry Jack	16-0227-00	1.70	E-5|16|8				$2A^{SRT}$	2Bdg	No	2Bd
Lizz*	16-0199-00	1.85				NA-H|Y|U	$2A^{SRT}$	2Bdg	No	2Bd
Mulligan*	16-0389-00	0.94				NA-H|Y|U	$2A^{SRT}$	2Bdg	No	2Bd
Omega (Onega)*	16-0353-00	1.80					$2A^{SRT}$	2Bdg	No	2Bd
Otto, South*	16-0323-00	0.90					$2A^{SRT}$	2Bdg	No	2Bd
Vista*	16-0224-00	2.00					$2A^{LAT}$	2Bdg	No	2Bd
Wanihigan*	16-0349-00	1.70					$2A^{SRT}$	2Bdg	No	2Bd

*** Partially or fully within the Boundary Waters Canoe Area Wilderness.**

Cone, Upper Lake (16-0412-00): Upper Cone Lake is currently designated Class 2A to protect stream trout. This lake is not currently managed for stream trout nor is it a MNDNR designated trout lake (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Oxythermal conditions in this lake were determined to be suitable for Lake Trout but MNDNR fisheries surveys (1971, 1981, 1984, 1987 and 1998) did not capture Lake Trout, Lake Whitefish, Cisco, or stream trout. The MNDNR determined that Lake Trout introduction would not be successful due a small total volume of suitable water, the presence of Walleye, Smallmouth Bass (*Micropterus dolomieu* Lacepède, 1802), and Northern Pike, and a limited forage base. Considering this information, it is reasonable to assign Class 2Bdg to Upper Cone Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Devilfish Lake (16-0029-00): Devilfish Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which noted that it has "marginal" dissolved oxygen and that it was reclaimed in 1959. Lake Trout are considered to be native to this lake, but this species was stocked on an almost annual basis from 1961-1980. It was considered a marginal Lake Trout lake and the introduction of Rainbow Smelt in the early 1970s likely contributed to a decline in the Lake Trout population. In the 10 MNDNR fisheries surveys conducted on Devilfish Lake after November 28, 1975, none captured Lake Trout, Lake Whitefish, or Cisco. Brook Trout were collected in 1985 but these fish were determined to be transient fish from a connected stream trout stream. Temperature-oxygen conditions have consistently been marginal for Lake Trout. Based on this information, the Lake Trout population does not appear to have been sustainable on or after November 28, 1975 and the trout in surveys following this date were the result of stockings. Considering this information, it is reasonable to assign Class 2Bdg to Devilfish Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Hungry Jack Lake (16-0227-00): Hungry Jack Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that Smallmouth Bass and Walleye are present. Lake Trout are considered to be native to this lake but were extirpated by the 1950s. Temperature-oxygen measurements for this lake have been mixed in terms of the suitability for Lake Trout. Numerous stockings have not resulted in natural recruitment or good carryover. It is possible that the introduction of Walleye impacted the ability of Hungry Jack Lake to support a sustainable population of Lake Trout. Based on this information, the Lake Trout population does not appear to have been sustainable on or after November 28, 1975. Lake Whitefish and Cisco have also not been sampled from this lake. Considering this information, it is reasonable to assign Class 2Bdg to Hungry Jack Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Lizz Lake (16-0199-00): Lizz Lake was designated Class 2A because this lake was a designated trout lake (Minn. R. 6264.0050). Management of stream trout in Lizz Lake was discontinued this lake was removed from MNDNR's designated trout lakes list (State of Minnesota 2024). Five fisheries surveys (1984, 1994, 1998, 2002, 2013) from this lake did not capture any Lake Trout, Lake Whitefish, or Cisco. As a result, it is reasonable to assign Class 2Bdg to Lizz Lake for the protection of cool and warm waters also protected as a source of drinking water.

Mulligan Lake (16-0389-00): Mulligan Lake was designated Class 2A because this lake was a MNDNR designated trout lake (Minn. R. 6264.0050). Management of stream trout in Mulligan Lake was discontinued this lake was removed from MNDNR's designated trout lakes list (State of Minnesota 2024). Five fisheries surveys (1985, 1990, 1993, 1997, 2004) from this lake did not capture any Lake Trout, Lake Whitefish, or Cisco. Considering this information, it is reasonable to assign Class 2Bdg to Mulligan Lake for the protection of cool and warm waters also protected as a source of drinking water.

Omega (Onega) Lake (16-0353-00): Omega Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which noted that it has "good" dissolved oxygen conditions. There is no record of a Lake Trout population in this lake. Limited fisheries data are available from

this remote lake in the BWCAW but a 1939 survey sampled only Northern Pike and recommended that fish should not be stocked into this lake until the Northern Pike population is reduced. Considering this information, it is reasonable to assign Class 2Bdg to Omega Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Otto, South Lake (16-0323-00): South Otto Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It was listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967), but there is no record of a population of Lake Trout or any other coldwater fish species in this lake. This lake has a small surface area (17 ha) which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to South Otto Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Vista Lake (16-0224-00): Vista Lake was designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which noted that it has "marginal" dissolved oxygen conditions. Two MNDNR fisheries surveys (1985 and 1993) did not collect any Lake Trout, Lake Whitefish, or Cisco and there is no evidence of a population of any coldwater species in this lake. Considering this information, it is reasonable to assign Class 2Bdg to Vista Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Wanihigan Lake (16-0349-00): Wanihigan Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. Minnesota Department of Conservation (1967) lists Wanihigan Lake as a "potential inland lake trout lake" but also noted that dissolved oxygen is "marginal" in this lake. There is no record of a population of Lake Trout or any other coldwater fish species in this lake. This lake has a small surface area (19 ha) and is relatively shallow (Z_{max} = 12 m) which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Wanihigan Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

b. Lake Superior – South watershed (04010102)

Class 2A confirmations

The following lakes will be confirmed for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designation confirmations is provided in Table 20 and additional evidence follows the table as needed. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lake Superior – South watershed (04010102).

Table 20. List of draft Class 2A use confirmations and designations for lakes in the Lake Superior – South watershed (04010102) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Bean (Lower Twin)	38-0409-00	2.34				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bear (Upper Twin)	38-0408-00	0.77	U-7|2|20			SPT-C|Y|U	$2A^{LAT,SRT}$	2Ag[LAT,SRT]	Yes	SC

Bear (Upper Twin) Lake (38-0408-00): Bear Lake is currently designated for protection of stream trout and Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Although Lake Trout are not native to this lake, this species has been stocked and has become established and is self-sustaining. Bear Lake is also managed for splake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout and stream trout (Class 2Ag [LAT,SRT]).

Class 2B/2Bd designations

The following lake will be designated for the protection warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the draft use designation is provided in Table 21 and additional details are provided following the table. For this lake, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering this information below, it is reasonable to assign Class 2Bdg to these lakes for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lake Superior – South watershed (04010102).

Table 21: List of draft Class 2B/2Bd use designations for lakes in the Lake Superior – South watershed (04010102) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout water	Type
Normanna	69-1383-00	1.02				NA-H|Y|U	2B	2Bg	Yes	2Bd
Unnamed	69-0122-00	10.65					$2A^{SRT}$	2Bdg	No	2Bd

Unnamed lake (69-0122-00): This unnamed lake was incorrectly designated Class 2A and is labeled as Normanna Lake in Minn. R. 7050.0470. However, this lake was never managed for stream trout. This waterbody is shallow (Z_{max} = 1.4 m) and has a small surface area (0.9 ha). As a result, the morphology of this lake is not suitable for Lake Trout, Lake Whitefish, Cisco, or the management of a stream trout fishery. The MNDNR designated and managed a separate, nearby lake called Normanna Lake (69-1383-00) for stream trout. Management of Brook Trout in Normanna Lake (69-1383-00) was discontinued in 2003 although the lake is still designated a trout lake by the MNDNR (Minn. R. 6264.0050). It is reasonable to remove the Class 2A designation from 69-0122-00 because it was erroneously designated. Normanna Lake (69-1383-00) will not be designated Class 2Ag [SRT] at this time

because the MNDNR no longer manages this lake for stream trout and because the MNDNR intends to remove this lake from its list of designated trout lakes.

Normanna Lake (69-1383-00): This lake was managed for Brook Trout until 2003 and is currently listed by the MNDNR as a trout lake (Minn. R. 6264.0050). However, this lake was never designated Class 2A by the MPCA due to an error (see Unnamed lake (69-0122-00)). The MNDNR is in the process of removing Normanna Lake from the list of trout lakes and as a result the MPCA is not proposing a change to the current Class 2B designation assigned by default.

c. St. Louis River watershed (04010201)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 22 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or the lakes are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the St. Louis River watershed (04010201).

Table 22. List of draft Class 2A use confirmations and designations for lakes in the St. Louis River watershed (04010201) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Corona (John)	09-0048-00	1.92				RBT-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Ely	69-0660-00	1.93	E-0|13|0		U-8|5|142		2B	2Ag[TLC]	No	2A
Esquagama	69-0565-00	1.36	E-0|6|0		P-6|0|499		2B	2Ag[TLC]	No	2A
Judson Mine Pit	69-1295-00	0.63				NA-H|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Little Elbow	69-1329-00	1.12				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Sabin	69-0434-01	2.72			P-8|1|138		2B	2Ag[TLC]	No	2A
Sabin (Embarrass Mine, Lake Mine)	69-0429-00	0.19	P-10|1|202		U-0|11|0	NA-H|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Spring Hole	69-1372-00	2.04				BKT-C|Y|N	$2A^{SRT}$	2Ag[SRT]	Yes	SC
St. Mary's	69-0651-00	2.34			P-5|0|117		2Bd	2Ag[TLC]	No	2A
Twin Lakes (Twin Ponds)	69-0967-01,-02	3.29-3.35				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Wynne	69-0434-02	2.07			P-8|1|255		2B	2Ag[TLC]	No	2A

Ely Lake (69-0660-00): Ely Lake is currently designated Class 2B and is not designated for the protection of coldwater fish species. Lake Trout are not considered to be native to this lake, but Lake Trout were stocked in 1912. Lake Trout in this lake were determined to not be sustainable and this species is no longer stocked. As a result, Ely Lake will not be designated for the protection Lake Trout. However, Ely Lake supports a natural population of Cisco. Considering this information, it is reasonable to designate Ely Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Esquagama Lake (69-0565-00): Esquagama Lake is currently designated Class 2B and is not designated for the protection of coldwater fish species. Lake Trout are not considered to be native to this lake, but Lake Trout were stocked in 1941. Lake Trout in this lake were determined to not be sustainable and this species is no longer stocked. As a result, Esquagama Lake will not be designated for the protection Lake Trout. However, Esquagama Lake supports a natural population of Cisco. Considering this information, it is reasonable to designate Esquagama Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Judson Mine Pit (69-1295-00): Judson Mine Pit is currently designated Class 2A to protect stream trout. Management of Rainbow Trout in Judson Mine Pit was discontinued although waterbody lake is still designated a trout lake by the MNDNR (Minn. R. 6264.0050). This waterbody is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this waterbody from the list of designated trout lakes or additional information indicates its removal is appropriate.

Little Elbow Lake (69-1329-00): Little Elbow Lake is currently designated Class 2A to protect stream trout. Management of Rainbow Trout in Little Elbow Lake was discontinued although the lake is still designated a trout lake by the MNDNR (Minn. R. 6264.0050). This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Sabin Lake (Embarrass Mine) (69-0429-00): Sabin Lake is currently designated Class 2A to protect stream trout. However, this waterbody is no longer managed for stream trout. The protections for stream trout will be retained until the MNDNR removes this waterbody from its list of designated trout lakes (Minn. R. 6264.0050) or additional information indicates its removal is appropriate. Lake Trout were also stocked in this waterbody and have established a self-sustaining population. There is uncertainty regarding the long-term management goals for this introduced species, and until that is resolved, a Lake Trout designation is not appropriate. Cisco have also been stocked in this waterbody. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and maintain protections for stream trout (Class 2Ag [SRT]).

d. Cloquet River watershed (04010202)

Class 2A designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these draft use designations is provided in Table 23 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Cloquet River watershed (04010202).

Table 23. List of draft Class 2A use confirmations and designations for lakes in the Cloquet River watershed (04010202) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Briar	69-0128-00	4.00				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Clearwater	69-0397-00	2.01				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Donna	69-0941-00	3.46				BNT-C|Y|U	2B	2Ag[SRT]	Yes	2A
Sand (Loraine)	69-0016-00	3.73				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Smith	69-0111-00	1.88			U-4|1|20		2B	2Ag[TLC]	No	2A

Donna Lake (69-0941-00): Donna Lake is currently designated Class 2B and is not designated for the protection of any coldwater fish species. The MNDNR added Donna Lake to Minn. R. 6264.0050 as a trout lake in 2018 (State of Minnesota 2018) because this lake supports a small, self-sustaining population of Brook Trout that migrate from a connected stream. In addition, the MNDNR intends to manage the lake as a put-and-take Brown Trout fishery. Considering this information, it is reasonable to assign Class 2Ag for the protection of coldwater habitat to this lake. The designation will be based on protections for stream trout and will be designated Class 2Ag [SRT].

Class 2Bd designations

The following lake will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the use designation is provided in Table 24 and additional details are provided following the table. For this lake, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering this information below, it is reasonable to assign Class 2Bdg to this lake for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Cloquet River watershed (04010202).

Table 24: List of draft Class 2Bd use designations for lakes in the Cloquet River watershed (04010202) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Mirror	69-0234-00	2.03				NA-H|N|U	$2A^{SRT}$	2Bdg	No	2Bd

Mirror Lake (69-0234-00): Mirror Lake is currently designated Class 2A to protect stream trout**.** Mirror Lake is proposed to be designated as a cool and warm water aquatic life and habitat also protected as a source of drinking water (Class 2Bdg). The MNDNR removed Mirror Lake from its designated trout lakes list (Minn. R. 6264.0050) in 2010 due to limited success of Brown Trout and splake stocking. Poor survivorship was attributed to the presence of undesirable cool water fish species. Five MNDNR fisheries surveys (1990, 1992, 1994, 1996, 2001) did not catch any Lake Trout, Lake Whitefish, or Cisco. Considering this information, it is reasonable to assign Class 2Bdg for the protection of cool and warm waters also protected as a source of drinking water (Class 2Bdg).

e. Nemadji River watershed (04010301)

No draft use designations or confirmations.

2. Lake of the Woods basin

a. Rainy River - Headwaters watershed (09030001)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 25 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or the lakes are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Rainy River - Headwaters watershed (09030001).

Table 25. List of draft Class 2A use confirmations and designations for lakes in the Rainy River - Headwaters watershed (09030001) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Adams*	38-0153-00	1.47	E-0|4|0	P-4|0|267			$2A^{LAT}$	2Ag[LKW]	No	SM
Ahmakose*	38-0365-00	0.97	U-3|0|30				$2A^{LAT}$	2Ag[LAT]	No	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Ahsub*	38-0516-00	0.93	E-3|5|9		E-0|8|0	NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Alice*	38-0330-00	3.07		U-1|0|2	U-1|0|88		2Bd	2Ag[TLC]	No	2A
Alpine*	16-0759-00	2.39	U-2|2|3	U-4|0|471	U-2|2|359		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Alruss*	69-0005-00	1.32				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Amber*	38-0336-00	3.23		U-0|1|0	U-1|0|39		2Bd	2Ag[TLC]	No	2A
Amoeber*	38-0227-00	1.07	P-3|0|26		P-3|0|739		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Ashdick (Caribou)*	38-0210-00	1.69			U-1|0|54		$2A^{SRT}$	2Ag[TLC]	No	SM
Ashigan*	38-0502-00	1.55			U-1|0|18		2Bd	2Ag[TLC]	No	2A
Basswood*	38-0645-00	2.86	U-0|6|0	P-4|2|38	P-6|0|524		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Bat*	16-0752-00	0.79	P-4|1|77				$2A^{LAT}$	2Ag[LAT]	No	SC
Bear Island	69-0115-00	2.93	E-0|16|0		P-15|1|320		2B	2Ag[TLC]	No	2A
Bear Trap*	69-0089-00	2.28			U-1|0|102		2Bd	2Ag[TLC]	No	2A
Beaver (Elbow)*	38-0223-00	1.32			U-1|0|122		$2A^{SRT}$	2Ag[TLC]	No	SM
Beaver Hut	38-0737-00	3.56				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Beetle	38-0551-00	2.25				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bingshick*	16-0627-00	1.69				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Blue Snow*	16-0532-00	1.38	U-0|0|0				$2Bd^{LAT}$	2Ag[LAT]	No	2A
Boot*	38-0503-00	1.16			P-3|0|45		2Bd	2Ag[TLC]	No	2A
Burntside	69-0118-00	1.51	P-33|12|778	P-36|9|2193	E-22|23|649		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Cash (Cache)*	16-0438-00	1.52	U-1|0|5				$2A^{LAT}$	2Ag[LAT]	No	SC
Cedar	38-0810-00	2.69			P-5|8|24		2Bd	2Ag[TLC]	No	2A
Chant	69-0172-00	1.41				RBT,BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Cherokee*	16-0524-00	1.00	P-4|0|14				$2A^{LAT}$	2Ag[LAT]	No	SC
Cherry*	38-0166-00	1.03	P-3|0|11		P-3|0|193		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Clearwater*	38-0638-00	2.86		U-1|0|7			2Bd	2Ag[LKW]	No	2A
Conchu*	38-0720-00	1.03				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Crab*	69-0220-00	2.06			U-2|1|13		$2A^{SRT}$	2Ag[TLC]	No	SM

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Crooked*	38-0817-00	3.71		U-3|0|18	U-3|0|340		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM
Crooked*	16-0723-00	1.37	P-4|0|78				$2A^{LAT}$	2Ag[LAT]	No	SC
Cruiser#	69-0832-00	0.95	P-5|0|230				$2A^{LAT}$	2Ag[LAT]	No	SC
Cub	69-1318-00	1.07				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Cummings*	69-0325-00	3.23			P-2|0|47		2Bd	2Ag[TLC]	No	2A
Dan	38-0853-00	1.65				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Devils Elbow*	16-0616-00	1.42		U-2|0|22	U-2|0|22		2Bd	2Ag[LKW,TLC]	No	2A
Disappointment*	38-0488-00	2.66			U-8|0|883		2Bd	2Ag[TLC]	No	2A
Dry	69-0064-00	1.80			P-17|0|1275	BNT, SPT-C|Y|U	$2A^{SRT}$	2Ag[TLC,SRT]	Yes	SM
Eddy*	38-0187-00	1.01	U-0|2|0	U-2|0|260			$2A^{LAT}$	2Ag[LAT,LKW]	No	SM
Eikala	38-0677-00	1.47				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Ester (Gnig)*	38-0207-00	1.04	P-2|0|33	P-2|0|154	P-1|1|26		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Eugene*	69-0473-00	1.60		P-4|0|55	U-3|1|5		$2A^{SRT}$	2Ag[LKW]	No	SM
Explorer*	38-0399-00	0.93	U-1|0|25				$2A^{LAT}$	2Ag[LAT]	No	SC
Extortion	16-0450-00	1.48				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Farm*	38-0779-00	2.80		U-3|16|5	P-19|0|1544		2Bd	2Ag[TLC]	No	2A
Fat*	69-0481-00	1.69	U-6|0|382				$2A^{LAT}$	2Ag[LAT]	No	SC
Fay*	16-0783-00	1.16	U-2|0|5				$2A^{LAT}$	2Ag[LAT]	No	SC
Fenske	69-0085-00	1.95			P-9|1|72		2Bd	2Ag[TLC]	No	2A
Fern*	16-0716-00	1.09	U-2|0|12				$2A^{LAT}$	2Ag[LAT]	No	SC
Finger*	69-0348-00	1.77			U-1|0|151		$2A^{SRT}$	2Ag[TLC]	No	SM
Fishdance*	38-0343-00	1.86		U-1|0|53	U-1|0|179		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM
Found*	38-0620-00	1.91				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Fraser*	38-0372-00	1.29	U-2|0|25		U-2|0|290		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
French*	16-0755-00	0.64	U-3|0|6				$2A^{LAT}$	2Ag[LAT]	No	SC
Frost*	16-0571-00	1.34	U-3|0|50				$2A^{LAT}$	2Ag[LAT]	No	SC
Gabbro*	38-0701-00	2.97			P-3|0|288		2Bd	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Gabimichigami*	16-0811-00	0.74	P-4|0|69				$2A^{LAT}$	2Ag[LAT]	No	SC
Garden	38-0782-00	2.39		U-1|16|1	P-17|0|568		2B	2Ag[TLC]	No	2A
Ge-Be-On-Equat*	69-0350-00	2.41		P-6|0|81	P-5|1|191		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM
Gibson*	38-0508-00	2.63			U-1|0|11		2Bd	2Ag[TLC]	No	2A
Gift*	38-0162-00	1.87		U-1|0|119			2Bd	2Ag[LKW]	No	2A
Gijikiki (Cedar)*	38-0209-00	1.04	U-1|0|6				$2A^{LAT}$	2Ag[LAT]	No	SC
Gillis*	16-0753-00	0.72	P-4|0|188				$2A^{LAT}$	2Ag[LAT]	No	SC
Glacier Pond 1	38-0712-01	4.41				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Glacier Pond 2	38-0712-02	1.26				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Gneiss*	16-0617-00	1.04	U-2|0|4	U-2|0|31	U-2|0|231		$2Bd^{LAT}$	2Ag[LAT,LKW,TLC]	No	2A
Good*	38-0726-00	1.87		P-1|2|1	P-3|0|149		2Bd	2Ag[TLC]	No	2A
Gordon*	16-0569-00	0.97	U-1|1|1				$2A^{LAT}$	2Ag[LAT]	No	SC
Granite*	16-0580-00	1.48		U-1|0|10	U-1|0|84		2Bd	2Ag[LKW,TLC]	No	2A
Gull*	16-0632-01	2.32		P-6|0|64	P-6|0|125		2Bd	2Ag[LKW,TLC]	No	2A
Gun*	69-0487-00	0.72	U-3|0|44		U-3|0|89		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Gunflint	16-0356-00	0.89	P-15|0|460		P-15|0|360		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Gypsy	38-0665-00	2.87				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Hanson*	38-0206-00	1.08	P-2|0|27	P-2|0|139	P-2|0|24		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Hanson	69-0189-00	0.83				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Harriet	38-0048-00	3.00		U-2|10|2			2B	2Ag[LKW]	Yes	2A
Heritage*	69-0469-00	2.46			U-2|0|114		2Bd	2Ag[TLC]	No	2A
High	69-0071-00	1.61				BKT,RBT,SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Hogback and Canal[19]	38-0057-01, -02	1.35-1.17				RBT, SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Holt*	38-0178-00	1.18	U-1|0|10				$2A^{LAT}$	2Ag[LAT]	No	SC

[19] Both basins are listed together as Hogback (Twin) Lake in Minn. R. 6264.0050.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Horseshoe*	38-0580-00	2.47		U-1|0|20	U-1|0|22		2Bd	2Ag[LKW,TLC]	No	2A
Howard*	16-0789-00	0.78	U-2|0|51				$2A^{LAT}$	2Ag[LAT]	No	SC
Hudson*	38-0484-00	3.36		U-1|0|9	U-1|0|64		2Bd	2Ag[LKW,TLC]	No	2A
Hustler*	69-0343-00	1.43			P-4|1|47		$2A^{SRT}$	2Ag[TLC]	No	SM
Ima*	38-0400-00	1.18	U-3|1|64		U-4|0|344		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Insula*	38-0397-00	3.09		U-4|0|15	U-4|0|415		2Bd	2Ag[LKW,TLC]	No	2A
Iron*	69-0121-00	2.73		P-1|1|1	P-2|0|122		2Bd	2Ag[TLC]	No	2A
Jacob (Louis)*	69-0077-00	1.08				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Jasper*	16-0768-00	0.84	U-2|0|10	U-2|0|38			$2A^{LAT}$	2Ag[LAT,LKW]	No	SM
Jenny*	38-0194-01, -02	0.67 -0.81		U-1|0|63			2Bd	2Ag[LKW]	No	2A
Johnson	69-0691-00	1.90	E-1|9|3	P-10|0|514	P-9|1|663		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Jordan*	38-0511-00	1.39			U-1|0|6		2Bd	2Ag[TLC]	No	2A
Jouppi	38-0909-00	2.09				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Karl*	16-0461-00	1.17	U-1|1|1				$2A^{LAT}$	2Ag[LAT]	No	SC
Kek (Little Kekekabic)*	38-0228-00	0.55	U-1|0|18				$2A^{LAT}$	2Ag[LAT]	No	SC
Kekekabic*	38-0226-00	0.86	P-3|0|137				$2A^{LAT}$	2Ag[LAT]	No	SC
Kingfisher*	16-0812-00	1.73	U-1|0|1	U-1|0|28			2Bd	2Ag[LKW]	No	2A
Knife*	38-0404-00	1.57	P-7|0|154	P-7|0|717	P-7|0|808		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Lac la Croix*	69-0224-00	2.16	P-5|2|172	P-6|1|479	P-6|1|2092		$2Bd^{LAT}$	2Ag[LAT,LKW,TLC]	No	2A
Lake of the Clouds (Dutton)*	38-0169-00	0.56	U-0|1|0[20]				$2A^{LAT}$	2Ag[LAT]	No	SC
Link*	38-0163-00	2.19		U-1|0|14			2Bd	2Ag[LKW]	No	2A
Little Dry	69-1040-00	1.89			U-6|11|75	BNT,SPT-C|Y|U	$2A^{SRT}$	2Ag[TLC,SRT]	Yes	SM
Little Knife*	38-0229-00	0.65	P-5|1|50	P-6|0|418	P-6|0|393		$2Bd^{LAT}$	2Ag[LAT,LKW,TLC]	No	2A

[20] In addition to a standard gill net survey in 1973, test netting was performed in 1980 following the stocking of lake trout. The test netting sampled 8 lake trout.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Little Long	69-0066-00	2.46	E-0|12|0		U-8|4|392		2Bd	2Ag[TLC]	No	2A
Little Loon*	69-0484-00	1.38		U-1|0|1	U-1|0|20		2Bd	2Ag[TLC]	No	2A
Little Saganaga*	16-0809-00	1.11	P-4|0|34				$2A^{LAT}$	2Ag[LAT]	No	SC
Little Shell*	69-0384-00	2.02			U-1|0|28		2Bd	2Ag[TLC]	No	2A
Little Trout#	69-0682-00	1.1	U-8|1|69		P-8|1|194		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Little Vermilion*	69-0608-00	2.43		U-4|2|6	P-6|0|1332		2Bd	2Ag[TLC]	No	2A
Long Island*	16-0460-00	2.39	P-3|0|23				$2A^{LAT}$	2Ag[LAT]	No	SC
Loon*	69-0470-00	2.34	U-1|5|1	P-6|0|44	P-6|0|269		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Loon	16-0448-00	0.70	P-16|0|414		P-16|0|1804		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Lunar (Moon)*	38-0168-00	1.48	U-1|0|14				$2A^{LAT}$	2Ag[LAT]	No	SC
Lynx*	69-0383-00	1.26			U-2|0|56		$2A^{SRT}$	2Ag[TLC]	No	SM
Magnetic	16-0463-00	1.03	U-3|0|16		U-3|0|80		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Makwa (Bear)*	38-0147-00	1.17	U-1|0|4				$2A^{LAT}$	2Ag[LAT]	No	SC
Malberg*	38-0090-00	3.18		P-2|0|118	M-1|1|43		2Bd	2Ag[LKW]	No	2A
Marabaeuf*	16-0610-00	2.12	U-1|1|5	U-2|0|57	U-2|0|71		$2Bd^{LAT}$	2Ag[LAT,LKW,TLC]	No	2A
Mavis*	16-0528-00	0.79				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Mayhew	16-0337-00	1.20	P-14|0|182			RBT-C|N|U	$2A^{LAT}$	2Ag[LAT,SRT]	No	SM
Meditation*	16-0583-00	1.96				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Memegwesi	38-0440-00	2.24				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Mesaba*	16-0673-00	1.53	U-2|1|3				$2A^{LAT}$	2Ag[LAT]	No	SC
Miner's Pit	69-1293-01, -02	0.64	E-0|4|0			BKT,BNT, RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Missing Link*	16-0529-00	2.57				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Missionary*	38-0398-00	1.15	U-1|0|14				$2A^{LAT}$	2Ag[LAT]	No	SC
Moose*	38-0644-00	2.41		U-7|7|12	U-12|2|711		2Bd	2Ag[LKW,TLC]	No	2A
Mudro*	69-0078-00	1.06	U-0|4|0		P-3|1|55		2Bd	2Ag[TLC]	No	2A
Mukooda#	69-0684-00	1.77	P-9|1|115		P-10|0|2302		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Namakan#	69-0693-00	1.82	U-0|47|0	P-34|13|151	P-47|0|5072		2Bd	2Ag[LKW,TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Neglige*	38-0492-00	1.06				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Newfound*	38-0619-00	2.92		P-5|8|11	P-13|0|2398		2Bd	2Ag[LKW,TLC]	No	2A
Newton*	38-0784-00	2.65		U-2|8|3	U-9|1|88		2Bd	2Ag[TLC]	No	2A
Norberg	69-1312-00	1.57				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
North (Little North)	16-0331-00	1.01	U-2|0|71		U-2|0|54		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
North Branch Kawishiwi*	38-0738-00	2.30			U-1|0|26		2Bd	2Ag[TLC]	No	2A
Norway	38-0688-00	2.53				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Ogishkemuncie*	38-0180-00	1.97	P-5|0|17	P-5|0|499			$2A^{LAT}$	2Ag[LAT,LKW]	No	SM
Ojibway	38-0640-00	0.99	P-18|2|230		P-20|0|3395		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
One*	38-0605-00	2.51		P-4|3|25	P-7|0|253		2Bd	2Ag[LKW,TLC]	No	2A
Ottertrack (Cypress)*	38-0211-00	0.97	U-4|2|19	P-6|0|452	P-6|0|1831		$2Bd^{LAT}$	2Ag[LAT,LKW,TLC]	No	2A
Owl*	16-0726-00	1.10	U-2|0|3				$2A^{LAT}$	2Ag[LAT]	No	SC
Oyster*	69-0330-00	1.06	U-5|3|34		U-4|4|58		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Parent*	38-0526-00	2.41			P-10|0|880		2Bd	2Ag[TLC]	No	2A
Paulson*	16-0626-00	1.45	U-3|2|153			NA-H|Y|U	$2A^{LAT,SRT}$	2Ag[LAT]	No	SM
Peter*	16-0757-00	0.89	P-3|0|188				$2A^{LAT}$	2Ag[LAT]	No	SC
Portage	16-0327-00	1.77				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Portage*	38-0524-00	1.63			U-1|0|70		$2A^{SRT}$	2Ag[TLC]	No	SM
Powell*	16-0756-00	0.93	U-2|0|9				$2A^{LAT}$	2Ag[LAT]	No	SC
Rabbit*	38-0214-00	0.96	U-1|0|21				$2A^{LAT}$	2Ag[LAT]	No	SC
Raven*	38-0113-00	1.70	U-1|0|13				$2A^{LAT}$	2Ag[LAT]	No	SC
Red Rock*	16-0793-00	1.88	U-1|3|1	U-4|0|37	U-3|1|140		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Regenbogen	69-0081-00	1.41				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Rog*	16-0765-00	1.77				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Saganaga*	16-0633-00	2.74	P-14|1|178	P-15|0|1424	P-15|0|3905		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Sand Point#	69-0617-00	1.18		P-26|15|55	P-41|0|4737		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM
Scarp (Cliff)	38-0058-00	4.41				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Sea Gull*	16-0629-00	1.60	P-14|0|252	P-14|0|2172	U-11|3|248		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Section Eight	38-0258-00	1.70				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Section Twelve	38-0714-00	1.33			P-13|1|309		2B	2Ag[TLC]	No	2A
Sema*	38-0386-00	1.09	P-3|0|51				$2A^{LAT}$	2Ag[LAT]	No	SC
Shagawa	69-0069-00	3.78		U-2|16|5	P-18|0|1182		2B	2Ag[TLC]	No	2A
Shoofly	38-0422-00	1.89				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Skull*	38-0624-00	1.58	E-1|14|1			BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Slim*	69-0181-00	2.24	E-0|7|0		P-4|3|36		2Bd	2Ag[TLC]	No	2A
Snowbank*	38-0529-00	1.44	P-20|8|413		P-23|5|1465		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
South Farm*	38-0778-00	4.25			P-16|0|1699		2Bd	2Ag[TLC]	No	2A
South Hegman*	69-0075-02	1.56			P-6|0|135		2Bd	2Ag[TLC]	No	2A
Spoon (Fames)*	38-0388-00	1.23		P-1|1|58	M-1|1|36		$2A^{SRT}$	2Ag[LKW]	No	SM
Spring	69-0761-00	1.68	U-3|6|29	P-9|0|760	P-9|0|1007		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Steamhaul	38-0570-00	3.26				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Steep*	69-0475-00	2.07			P-2|0|6		2Bd	2Ag[TLC]	No	2A
Strup*	38-0360-00	0.72	U-0|0|0[21]				$2A^{LAT}$	2Ag[LAT]	No	SC
Stuart*	69-0205-00	3.45			P-4|3|32		2Bd	2Ag[TLC]	No	2A
Sucker*	38-0530-00	3.83		U-1|11|4	P-12|0|2097		2Bd	2Ag[TLC]	No	2A
Surber	16-0343-00	2.08				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Takucmich*	69-0369-00	0.75	P-6|0|77		P-6|0|475		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Thomas*	38-0351-00	1.47	P-2|1|23		P-2|1|157		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Three*	38-0600-00	3.90		P-1|1|21	P-2|0|57		2Bd	2Ag[LKW,TLC]	No	2A

[21] Eight lake trout were sampled in a 1978 fisheries survey.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Thumb*	69-0352-00	1.36			U-1|0|68		$2A^{SRT}$	2Ag[TLC]	No	SM
Toe*	69-0213-00	1.65			U-1|0|9		2Bd	2Ag[TLC]	No	2A
Tofte	38-0724-00	1.27			E-1|11|19	RBT, SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Topaz (Star)*	38-0172-00	1.82	U-1|1|5		P-2|0|284		$2A^{LAT}$	2Ag[TLC]	No	SM
Town*	16-0458-00	1.33	U-0|0|0[22]				$2A^{LAT}$	2Ag[LAT]	No	SC
Trappers	38-0431-00	4.20				BKT-C|Y|N	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Triangle	38-0715-00	2.52			P-10|1|317		2B	2Ag[TLC]	No	2A
Trip	16-0451-00	2.55				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Trygg (Twigg)*	69-0389-00	1.63				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Tuscarora*	16-0623-00	1.07	U-3|0|83				$2A^{LAT}$	2Ag[LAT]	No	SC
Two*	38-0608-00	3.61		P-3|1|12	P-4|0|185		2Bd	2Ag[LKW,TLC]	No	2A
Unnamed (Peanut)	38-0662-00	1.80				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Unnamed (Little Portage)	16-0297-00	1.77				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Unnamed (Pear)	38-0769-00	3.36				BKT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Unnamed (Judd)	38-0615-00	2.80				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Unnamed (Ennis)	38-0634-00	1.36				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Vera*	38-0491-00	1.88	E-0|5|0		U-4|1|492		$2A^{SRT}$	2Ag[TLC]	No	SM
West Fern*	16-0718-00	1.32	U-2|0|16				$2A^{LAT}$	2Ag[LAT]	No	SC
Windy	38-0068-00	3.11		P-12|0|1499			2B	2Ag[LKW]	No	2A
Wine*	16-0686-00	1.92	U-2|1|23				$2A^{LAT}$	2Ag[LAT]	No	SC
Wisini*	38-0361-00	0.62	U-2|0|67				$2A^{LAT}$	2Ag[LAT]	No	SC

*** Partially or fully within the Boundary Waters Canoe Area Wilderness.**

 # Partially or fully within Voyageurs National Park.

[22] One lake trout sampled in 1990.

Adams Lake (38-0153-00): The current Class 2A designation for Adams Lake was assigned to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not considered to be native to this lake but were historically stocked. Four MNDNR fisheries surveys did not sample any Lake Trout and this species is not considered to be self-sustaining in Adams Lake. As a result, Adams Lake is will not retain protections for Lake Trout. Adams Lake does support a natural population of Lake Whitefish as determined by the presence of this species in all four MNDNR fisheries surveys. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Ahsub Lake (38-0516-00): The current Class 2A designation for Ahsub Lake was assigned to protect stream trout. Management of stream trout in Ahsub Lake was discontinued although this lake is still a designated trout lake (Minn. R. 6264.0050). Lake Trout are not native to this lake but were stocked in 1979. This stocking did not result in a self-sustaining Lake Trout population. Cisco were also historically present in Ahsub Lake, but surveys from 1966-2005 did not sample this species and Cisco are considered extirpated. This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from its list of designated trout lakes or additional information indicates its removal is appropriate. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Alice Lake (38-0330-00): Alice Lake is currently designated Class 2Bd and is not designated for the protection of any coldwater fish species. Alice Lake was surveyed once in 1979 and a high number of Cisco (n=88) were sampled. In this survey, a fish specimen was identified as a Lake Whitefish, but this likely represents a misidentification. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Alice Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Alpine Lake (16-0759-00): The current Class 2A designation for Alpine Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that it has "marginal" dissolved oxygen conditions. Lake Trout are considered to be native to this lake, but available data are limited due to the difficulty of sampling this lake. Lake Trout were sampled in two MNDNR fisheries surveys of Alpine Lake (1982 and 1990). As a result, Alpine Lake will retain the designation for the protection of Lake Trout, but additional work may demonstrate the protection of Lake Trout is not an existing use. Based on MNDNR fisheries surveys, Alpine Lake supports natural populations of Cisco and Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Lake Whitefish, and Cisco (Class 2Ag [LAT,LKW,TLC]).

Ashdick Lake (38-0210-00): The current Class 2A designation for Ashdick Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "doubtful." A survey in 1973 did not sample any Lake Trout although high numbers of Cisco (n=54) were sampled indicating that Ashdick Lake supports a natural population of Cisco. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Ashigan Lake (38-0502-00): Ashigan Lake is currently designated Class 2Bd and is not designated for the protection of coldwater fish species. Ashigan Lake was surveyed once in 1974 and a moderate number of Cisco were collected (n=18). However, because this lake is in the BWCAW, it is reasonable to assign the Class 2Ag designation for the protection of Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Basswood Lake (38-0645-00): The current Class 2A designation for Basswood Lake was assigned to protect Lake Trout. Lake Trout are considered native to this lake although they were stocked in 1941. No MNDNR fisheries surveys (n=6) on the Minnesota side of Basswood Lake have sampled Lake Trout and most of the habitat considered suitable for Lake Trout is on the Canadian side of the lake. Basswood Lake supports a population of Lake Trout although the fish are more prevalent on the Canadian side of the lake. Due to the size and complexity of Basswood Lake, application of standards to protect Lake Trout on the Minnesota side of the lake are not appropriate. If it can be determined that Lake Trout habitat is present on the Minnesota side of this lake, then designation of Lake Trout can be pursued. However, without the demonstration that Lake Trout habitat is present on the Minnesota side, assessment errors could occur due to natural conditions. Basswood Lake does support natural populations of Cisco and Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is partially within the BWCAW and therefore retains the prohibited ORVW designation.

Bear Trap Lake (69-0089-00): Bear Trap Lake is currently designated Class 2Bd and is not designated for the protection of coldwater fish species. Bear Trap Lake was surveyed once in 1973 and a high number of Cisco were collected (n=102). However, because this lake is in the BWCAW, it is reasonable to assign the Class 2Ag designation for the protection of Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Beaver (Elbow) Lake (38-0223-00): Beaver Lake is designated Class 2A to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967), but there is no record of a Lake Trout population in this lake. Beaver Lake was surveyed once in 1964 and a high number of Cisco were collected (n=122). This lake is in the BWCAW and it is reasonable to assign the Class 2Ag designation for the protection of Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Beaver Hut Lake (38-0737-00): Beaver Hut Lake is designated Class 2A to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). Management of stream trout in Beaver Hut Lake was discontinued due to low survival and poor summer oxythermal conditions. However, this lake is still a designated by the DNR as a trout lake (Minn. R. 6264.0050). Beaver Hut Lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Blue Snow Lake (16-0532-00): Blue Snow Lake is currently designated Class 2Bd, but it is listed for the protection of Lake Trout. There are no MNDNR fisheries surveys to demonstrate the presence of a population of Lake Trout. The lack of monitoring is due to its location in the BWCAW and the lack of an established portage to reach this lake. However, there are numerous angler reports, as recent as 2013, which indicate that Lake Trout are present in

Blue Snow Lake. As a result, it is reasonable to designate Blue Snow Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout (Class 2Ag [LAT]). Due to the lack of monitoring data, it is possible that additional information could result in a change to this designation.

Clearwater Lake (38-0638-00): Clearwater Lake is currently designated Class 2Bd and is not designated for the protection of any coldwater fish species. It was surveyed once in 1977 and 7 Lake Whitefish were collected. However, because this lake is in the BWCAW it is reasonable to designate Clearwater Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Conchu Lake (38-0720-00): Conchu Lake is designated Class 2A to protect stream trout, but management of stream trout has been discontinued. However, this lake is still a designated trout lake on the MNDNR's designated trout lakes list (Minn. R. 6264.0050). Conchu Lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Crab Lake (69-0220-00): The current Class 2A designation for Crab Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "doubtful." Three fisheries surveys from 1950 through 2001 did not sample any Lake Trout. However, based on these fisheries surveys, Crab Lake does support a natural population of Cisco. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Crooked Lake (38-0817-00): The current Class 2A designation for Crooked Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "Minnesota-Ontario boundary potential lake trout lake" in Minnesota Department of Conservation (1967). Three fisheries surveys from 1983 through 2007 did not sample any Lake Trout. Fisheries surveys do indicate that Crooked Lake supports natural populations of Cisco and Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [LKW,TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Eddy Lake (38-0187-00): The current Class 2A designation for Eddy Lake was assigned to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "good." Lake Trout are considered to be native to this lake. This lake is in the BWCAW and there is limited water quality and fisheries information. Two MNDNR fisheries surveys were conducted in 1972 and 1985 and one Lake Trout was captured in the 1972 survey. Lake Trout fingerlings were stocked from 1976-1979 and 1982 and some Lake Trout were reported in a winter 1979 creel census. Indications are that there was minimal or no survival of stocked fish and that there is not an extant population in this lake. Since there is limited information and the existing use status of the Lake Trout population cannot be determined, the protections for Lake Trout will be retained. Additional information could result in the removal of the Lake Trout designation if appropriate. Eddy Lake does support a

natural population of Lake Whitefish which should be protected. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Trout and Lake Whitefish (Class 2Ag [LAT,LKW]).

Eugene Lake (69-0473-00): The current Class 2A designation for Eugene Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "fair." This lake is in the BWCAW and there is limited water quality and fisheries information. Four MNDNR fisheries surveys were conducted between 1965 and 2016 and no Lake Trout were captured. Eugene Lake does support a natural population of Lake Whitefish which should be protected. Low numbers of Cisco were also collected in three MNDNR fisheries surveys from 1965 through 2001. This lake will not be designated for the protection of Cisco until additional data can be collected. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Explorer Lake (38-0399-00): The current Class 2A designation for Explorer Lake was assigned to protect Lake Trout. Explorer Lake was surveyed once in 1972 and a moderate number of Lake Trout (n=25) were sampled. This lake is in the BWCA and despite limited monitoring data from Explorer Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to limited monitoring data (i.e., a single fisheries survey) from this lake, it is possible that additional information could result in a change to this designation.

Farm Lake (38-0779-00): Farm Lake is currently designated Class 2Bd and is not designated for the protection of coldwater fish species. Nineteen MNDNR fisheries surveys have been conducted and every survey sampled Cisco indicating that this lake supports a good population of Cisco. In addition to Cisco, Lake Whitefish have also been sampled in Farm Lake. However, Lake Whitefish have been irregularly sampled and the status of a potential population is unknown. Farm Lake is connected to the Kawishiwi River and thereby to other lakes supporting Lake Whitefish which could be the source of transient fish. Additional sampling is recommended, particularly using deep-set gill nets, to determine if Farm Lake should also be protected for Lake Whitefish. Considering this information, it is reasonable to designate Farm Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Fay Lake (16-0783-00): The current Class 2A designation for Fay Lake was assigned to protect Lake Trout. Fay Lake was surveyed twice (1986 and 1996) and 5 Lake Trout were sampled. Lake Trout were also observed in the first survey conducted in 1939. This lake is in the BWCAW and despite limited sampling for Fay Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., two fisheries surveys indicating a small population), it is possible that additional information could result in a change to this designation.

Finger Lake (69-0348-00): The current Class 2A designation for Finger Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "fair." This lake is in the BWCAW and there is limited water quality and fisheries information, but there is no evidence of a Lake Trout population. Finger Lake was surveyed once in 1980 and a high number of Cisco (n=151) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Finger Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data from this lake (i.e., a single fisheries survey), it is possible

that additional information could result in a change to this designation. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Fishdance Lake (38-0343-00): The current Class 2A designation for Fishdance Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). This lake is in the BWCAW and there is limited water quality and fisheries information. A single MNDNR fisheries survey was conducted in 1964 and no Lake Trout were captured. However, during this single survey, high numbers of Cisco (n=100) and Lake Whitefish (n=53) were sampled indicating that this lake does support natural populations of these coldwater fishes. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [TLC,LKW]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation. Due to the limited monitoring data from this lake (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Fraser Lake (38-0372-00): The current Class 2A designation for Fraser Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) and notes that "walleyes dominate." Fraser Lake was surveyed twice (1976 and 1986) and 25 Lake Trout were sampled. Angler reports indicate that Lake Trout are still likely present, but additional sampling is recommended to confirm the presence of Lake Trout. This lake is in the BWCAW and despite limited monitoring data from Fraser Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data from this lake (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

French Lake (16-0755-00): The current Class 2A designation for French Lake was assigned to protect Lake Trout. French Lake was surveyed three times (1982, 1992, and 1996) and 6 Lake Trout were sampled. This lake is in the BWCAW and despite limited monitoring data from French Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data for this lake (i.e., limited sampling and low Lake Trout abundance), it is possible that additional information could result in a change to this designation.

Garden Lake (38-0782-00): Garden Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Seventeen MNDNR fisheries surveys have been conducted in Garden Lake which have demonstrated that this lake supports a population of Cisco. A single Lake Whitefish was also sampled in 1989, but this fish may have been transient. Garden Lake is connected to the Kawishiwi River and through this waterway to other lakes supporting Lake Whitefish which could be the source of transient fish. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Garden Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Ge-Be-On-Equat Lake (69-0350-00): The current Class 2A designation for Ge-Be-On-Equat Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "poor." Five MNDNR fisheries surveys have been conducted between 1981 and 2009 and no Lake Trout have been sampled. However, during these surveys, Cisco and Lake Whitefish were sampled during most surveys, indicating

that this lake supports natural populations of these coldwater fishes. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [TLC,LKW]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Gibson Lake (38-0508-00): Gibson Lake is currently designated Class 2Bd and is not designated for the protection of coldwater fish species. Gibson Lake was surveyed once in 1982 and a moderate number of Cisco (n=11) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Gibson Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data from this lake (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Gift Lake (38-0162-00): Gift Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Gift Lake was surveyed once in 1973 and a high number of Lake Whitefish (n=119) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Gift Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Gijikiki Lake (38-0209-00): The current Class 2A designation for Gijikiki Lake is based on protections for Lake Trout. Gijikiki Lake was surveyed once in 1976 and a moderate number of Lake Trout (n=6) were sampled. This lake is in the BWCAW and despite limited monitoring data from Gijikiki Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Gneiss Lake (16-0617-00): The current Class 2A designation for Gneiss Lake was assigned to protect Lake Trout. Gneiss Lake was surveyed twice (1978 and 1999) and low numbers of Lake Trout were sampled (n=4). However, Lake Trout were sampled in both fisheries surveys indicating the possible presence of a natural population of this species although this lake is also connected to Marabaeuf Lake (16-0610-00) and Gunflint Lake (16-0356-00). Moderate to high numbers of Lake Whitefish and Cisco were also sampled in these two surveys. This lake is in the BWCAW and despite limited monitoring data from Gneiss Lake, it is reasonable to retain the Class 2Ag designation for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Lake Whitefish, and Cisco (Class 2Ag [LAT,LKW,TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Good Lake (38-0726-00): Good Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Good Lake has been surveyed by the MNDNR three times (1975, 1988, and 2019) and Cisco were collected in all three surveys. A single Lake Whitefish was also sampled in 2019, but this fish may have been transient from Basswood Lake (38-0645-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Good Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Gordon Lake (16-0569-00): Gordon Lake is currently designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) and a single Lake Trout was sampled in two MNDNR fisheries surveys. However, this fish was possibly transient as Gordon Lake is connected to Cherokee (16-0524-00) and Long Island (16-0460-00) lakes. Gordon lake is deep (Z_{max} = 29 m) with a low geometry ratio (0.97), but it is also relatively small (58 ha) indicating that the extent of Lake Trout habitat in this lake would be limited. The available data suggest that a small population of Lake Trout is possibly preset in Gordon which may be supplemented by connected lakes. However, the presence or absence of such a population cannot be confirmed based on these data. Due to the limited information for Gordon Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., two fisheries surveys) and low catch, it is possible that additional information could result in a change to this designation.

Granite Lake (16-0580-00): Granite Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Granite Lake was surveyed once in 1978 and a moderate number of Lake Whitefish (n=10) and a high number of Cisco (n=84) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Granite Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Gull Lake (16-0632-01): Gull Lake is delineated into two basins in the MPCA's waterbody database. Only the main basin (16-0632-01) appears to be deep enough to support coldwater fish species. The other basin, southeast basin of Gull Lake (16-0632-02), is shallow (Z_{max} = 1.2 m) and unlikely to support coldwater fishes during the period of maximum oxythermal stress. The MNDNR has consistently sampled Lake Whitefish and Cisco in this lake indicating that these species are supported in this lake. Considering this information, it is reasonable to designate the main basin of Gull Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Harriet Lake (38-0048-00): Harriet Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Lake Whitefish (n=2) were sampled in Harriet Lake in two MNDNR fisheries surveys, including a 2013 MNDNR survey indicating this species is present. In addition, Lake Whitefish were harvested by commercial fishermen in 1981 from Harriet Lake. Despite limited numbers of Lake Whitefish in fisheries surveys, it is reasonable to designate Harriet Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

Hogback (Twin) Lake (38-0057-01,-02): Hogback Lake consists of two distinct bays and both are designated trout lakes (Minn. R. 6264.0050). It is reasonable to retain a Class 2Ag for the protection of stream trout (Class 2Ag [SRT]) in both bays. These bays are named Hogback (38-0057-01) and Canal (38-0057-02) and this nomenclature will be clarified in Minn. R. 7050.0470 as part of this revision.

Holt Lake (38-0178-00): The current Class 2A designation for Holt Lake was assigned to protect Lake Trout. Holt Lake was surveyed once in 1979 and a moderate number of Lake Trout (n=10) were sampled. This lake is in the BWCAW and despite limited monitoring data from Holt Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Horseshoe Lake (38-0580-00): Horseshoe Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Moderate numbers of Lake Whitefish (n=20) and Cisco (n=22) were sampled in Horseshoe Lake in fisheries surveys in 1963 and 1992. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Horseshoe Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Hudson Lake (38-0484-00): Hudson Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Moderate numbers of Lake Whitefish (n=9) and high numbers of Cisco (n=64) were sampled in Hudson Lake in a fisheries survey in 1962. Cisco were also present in a 1992 survey. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Hudson Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Hustler Lake (69-0343-00): The current Class 2A designation for Hustler Lake was assigned to protect stream trout although this lake is not included on the MNDNR's trout lakes list (Minn. R. 6264.0050). It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). There have been six MNDNR fisheries surveys on Hustler Lake and no Lake Trout were sampled. However, during four of the six surveys, Cisco were sampled indicating that this lake supports a natural population of this coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Iron Lake (69-0121-00): Iron Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Two MNDNR fisheries surveys have been conducted on Iron Lake which have demonstrated that this lake supports a population of Cisco. A single Lake Whitefish was also sampled in 2018, but this fish may have been transient from Crooked Lake (38-0817-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Iron Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Jenny Lake (38-0194-01,-02): Jenny Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Jenny Lake was surveyed once in 1980 and a high number of Lake Whitefish (n=63) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Jenny Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Jordan Lake (38-0511-00): Jordan Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Two MNDNR fisheries surveys have been conducted on Jordan Lake which have demonstrated that this lake supports a population of Cisco. A single Lake Whitefish was also sampled in 2018, but this fish may have been transient from Ima Lake (38-0400-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this

information, it is reasonable to designate Jordan Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Johnson Lake (69-0691-00): The current Class 2A designation for Johnson Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not considered native in this lake and were stocked. Ten MNDNR fisheries surveys have been conducted between 1970 and 2016 and Lake Trout were only collected in 2016 (n=3). Lake Trout are no longer stocked and based on surveys this species is not considered sustainable in Johnson Lake. However, during the MNDNR fisheries surveys, Cisco and Lake Whitefish were sampled during most surveys, indicating that this lake supports natural populations of these coldwater fishes. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [TLC,LKW]). The removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) assigned to Johnson Lake.

Karl Lake (16-0461-00): Karl Lake is currently designated Class 2A to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that it has "good" dissolved oxygen conditions. A single Lake Trout was sampled in a MNDNR fisheries survey in 1983, but the species was absent from a second survey in 1996. Karl Lake is broadly connected to Long Island Lake (16-0460-00) which could have been the source of the Lake Trout. Karl lake is relatively deep (Z_{max} = 21 m) with a low geometry ratio (1.17), but it is also relatively small (51 ha). Most of the lake is shallow indicating that the extent of Lake Trout habitat in this lake would be limited. The available data suggest that a small population of Lake Trout is possibly present in Karl which is supplemented by fish from Long Island Lake. However, the presence or absence of such a population cannot be confirmed based on these data. Due to the limited information for Karl Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., two fisheries surveys) and low catch, it is possible that additional information could result in a change to this designation.

Kek Lake (38-0228-00): The current Class 2A designation for Kek Lake was assigned to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Kek Lake was surveyed once in 1988 and a moderate number of Lake Trout (n=18) were sampled. This lake is in the BWCAW and despite limited monitoring data from Kek Lake, it is reasonable to assign a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Kingfisher Lake (16-0812-00): Kingfisher Lake is currently designated Class 2Bd. A single MNDNR fisheries survey was conducted in 1978 and a single Lake Trout was sampled, but this fish may have been transient from Ogishkemuncie Lake (38-0180-00). This lake will not be designated for the protection of Lake Trout until additional data can be collected to confirm the presence of a resident population of Lake Trout. However, during the MNDNR fisheries surveys, a moderate number of Lake Whitefish were sampled (n=28), indicating a good likelihood that this lake supports a natural population of this coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

Lake of the Clouds (38-0169-00): The current Class 2A designation for Lake of the Clouds was assigned to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake of the Clouds Lake was surveyed twice including a 1980 survey that sampled a moderate number of Lake Trout (n=8). A 1973 survey did not collect any Lake Trout. It is not clear if Lake Trout are native to this lake, but Lake Trout were stocked from 1976-1979 and the 1980 test netting indicated an above average population of trout. This lake is in the BWCAW and despite limited monitoring data from Lake of the Clouds, it is reasonable to assign a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Link Lake (38-0163-00): Link Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Link Lake was surveyed once in 1973 and a moderate number of Lake Whitefish (n=14) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Link Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Little Long Lake (69-0066-00): Little Long Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Twelve MNDNR fisheries surveys have been performed and none sampled Lake Trout. Eight of the MNDNR fisheries surveys did sample Cisco indicating that this lake supported a population of Cisco. However, Cisco were last sampled in 2004 and were likely extirpated by the introduction of Rainbow Smelt. Since the Cisco population was native and occurred after November 28, 1975, this is an existing use and it should be protected. Considering this information, it is reasonable to designate Little Long Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Little Loon Lake (69-0484-00): Little Loon Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey was conducted in 2009 on Little Loon Lake and a moderate number of Cisco were sampled (n=20) indicating that this lake supports a population of Cisco. Despite limited sampling for Little Loon Lake, it is reasonable to assign protections for Cisco because this lake is in the BWCAW. A single Lake Whitefish was also sampled in 2009, but this fish may have been transient from Loon Lake (69-0470-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Little Loon Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Little Saganaga Lake (16-0809-00): The WID number for Little Saganaga Lake listed in Minn. R. 7050.0470 is incorrect. This lake is currently listed as 16-0890-00 and as part of this rule revision the WID number will be corrected to 16-0809-00.

Little Shell Lake (69-0384-00): Little Shell Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey was conducted in 1974 on Little Shell Lake and a moderate number of Cisco were sampled (n=28) demonstrating that this lake supports a population of Cisco. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Little Shell Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Little Vermilion Lake (69-0608-01, -02): Little Vermilion Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Six MNDNR fisheries surveys were conducted on Little Vermilion Lake and high numbers of Cisco were sampled (n = 1332) demonstrating that this lake supports a population of Cisco. Lake Whitefish were sampled in four of the six surveys with a total of 6 fish sampled, but these fish may have been transient from Sand Point Lake (69-0617-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Little Vermilion Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Loon Lake (69-0470-00): The current Class 2A designation for Loon Lake was assigned to protect Lake Trout. It is listed as a "Minnesota-Ontario boundary potential lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not considered native in this lake and were stocked. A single Lake Trout was sampled in 2008, but the other five surveys did not sample any Lake Trout. This species is no longer stocked and is not considered sustainable in this lake. However, during the MNDNR fisheries surveys, Cisco and Lake Whitefish were sampled in all six surveys, indicating that this lake supports natural populations of these coldwater fishes. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco and Lake Whitefish (Class 2Ag [TLC,LKW]). This lake is partially within the BWCAW and therefore retains the prohibited ORVW designation.

Lunar Lake (38-0168-00): The current Class 2A designation for Lunar Lake was assigned to protect Lake Trout. Lunar Lake was surveyed once in 1973 and a moderate number of Lake Trout (n=14) were sampled. This lake is in the BWCAW and despite limited monitoring data from Lunar Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Lynx Lake (69-0383-00): The current Class 2A designation for Lynx Lake was assigned to protect stream trout although it is not designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which noted that dissolved oxygen conditions are "good." There have been two MNDNR fisheries surveys (1974 and 2002) on Lynx Lake and no Lake Trout were sampled. However, during these surveys, Cisco were sampled in both indicating that this lake supports a natural population of this coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Makwa Lake (38-0147-00): The current Class 2A designation for Makwa Lake was assigned to protect Lake Trout and it is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Makwa Lake was surveyed once in 1980 and a small number of Lake Trout (n=4) were sampled. However, the sampling effort was small and only consisted of 2 gill nets. In addition, there are angler reports indicating that Lake Trout are present in this lake. This lake is in the BWCAW and despite limited monitoring data from Makwa Lake, it is reasonable to assign a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Malberg Lake (38-0090-00): Malberg Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Two MNDNR fisheries surveys have been conducted and both sampled Lake Whitefish. In the 1963 survey, a fish specimen was identified as a Cisco in Malberg Lake, but this possibly represents a misidentification. This lake will not be designated for the protection of Cisco until additional data can be collected to confirm the presence of a natural population of this species. As a result, it is reasonable to designate Malberg Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

Marabaeuf Lake (16-0610-00): Marabaeuf Lake is currently designated Class 2Bd and is also designated for the protection of Lake Trout. Marabaeuf Lake was surveyed twice (1978 and 1999) and low numbers of Lake Trout were sampled (n=5). Lake Trout were sampled in both fisheries surveys indicating the possible presence of a natural population of this species although this lake is also connected Gneiss Lake (16-0617-00). Good numbers of Lake Whitefish and Cisco were also sampled in these two surveys. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Marabaeuf Lake a Class 2Ag designation for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Lake Whitefish, and Cisco (Class 2Ag [LAT,LKW,TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Mesaba Lake (16-0673-00): Mesaba Lake is currently designated Class 2A to protect Lake Trout. Lake Trout are not considered native to Mesaba Lake and were stocked in 1977. Both fish surveys following stocking (1981 and 1993) sampled low numbers of Lake Trout for a total of 3 individuals indicating that if natural reproduction was occurring it was low. It is questionable whether Lake Trout are sustainable in this lake and there are no plans to stock additional Lake Trout in Mesaba Lake. Mesaba lake is relatively deep (Z_{max} = 20 m) with a low geometry ratio (1.53), but it is also relatively small (84 ha) so there is limited habitat for Lake Trout. The available data suggest that a small, introduced population of Lake Trout is possibly present in Mesaba Lake. However, the presence or absence of such a population cannot be confirmed based on these data. Due to the limited information for Mesaba Lake, it is reasonable to retain a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., two fisheries surveys) and low catch, it is possible that additional information could result in a change to this designation.

Missionary Lake (38-0398-00): The current Class 2A designation for Missionary Lake was assigned to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that it has "good" dissolved oxygen. Missionary Lake was surveyed once in 1979 and a moderate number of Lake Trout (n=14) were sampled. This lake is in the BWCAW and despite limited monitoring data from Missionary Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Mudro Lake (69-0078-00): Mudro Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Mudro Lake was stocked with Lake Trout, but no Lake Trout were sampled in the four MNDNR fisheries surveys conducted on this lake. Without additional data, this lake should not be designated for the protection of Lake Trout. However, MNDNR fisheries surveys did identify a population of Cisco in Mudro Lake. Considering this information, it is reasonable to assign the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Namakan Lake (69-0693-00): Namakan Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Lake Trout are possibly native to Namakan Lake, but no Lake Trout have been sampled in 47 MNDNR fisheries surveys. It is not clear if this lake can support a sustainable population of Lake Trout so at this time Namakan Lake will not be designated for the protection of Lake Trout. MNDNR fisheries surveys did identify populations of Cisco and Lake Whitefish in Namakan Lake. Considering this information, it is reasonable to designate Namakan Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Newton Lake (38-0784-00): Newton Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Ten MNDNR fisheries surveys have been conducted on Newton Lake and Cisco were present in nine of these surveys. This indicates that this lake supports a population of Cisco. Lake Whitefish were sampled in two of the ten surveys with a total of 3 fish sampled, but these fish may have been transient from Fall[23] (38-0811-00) or Basswood (38-0645-00) lakes. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Newton Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

North Branch of the Kawishiwi (38-0738-00): The North Branch of the Kawishiwi is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. This lake was surveyed once in 1978 and a moderate number of Cisco (n=26) were sampled. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate the North Branch of the Kawishiwi a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Owl Lake (16-0726-00): The current Class 2A designation for Owl Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that it has "good" dissolved oxygen. Owl Lake was surveyed twice (1980 and 1993) and low numbers of Lake Trout were sampled (n=3). This lake is in the BWCAW and despite limited monitoring data from Owl Lake, it is reasonable to assign a Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Paulson Lake (16-0626-00): The current Class 2A designation for Paulson Lake was assigned to protect stream trout. Paulson Lake was removed from the MNDNR's designated trout lakes list (Minn. R. 6264.0050) because it is no longer managed by the MNDNR for stream trout (State of Minnesota 2024). However, three surveys from 1986 through 2004 sampled moderate to high numbers of Lake Trout indicating that Paulson Lake does support a self-sustaining population of Lake Trout. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Trout (Class 2Ag [LAT]).

[23] Fisheries surveys indicate that Fall Lake appears to support Cisco and Lake Whitefish despite lake characteristics (both geometry ratio and temperature profiles) indicating that it is polymictic (see Appendix D).

Portage Lake (38-0524-00): The current Class 2A designation for Portage Lake was assigned to protect stream trout although it is not designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that dissolved oxygen conditions are "fair." This lake is in the BWCAW and there is limited water quality and fisheries information. A single MNDNR fisheries survey was conducted in 1979 and no Lake Trout were captured. However, during this single survey, high numbers of Cisco (n=70) were sampled indicating that this lake supports a natural population of this coldwater fish. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Powell Lake (16-0756-00): The current Class 2A designation for Powell Lake was assigned to protect Lake Trout and it is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Powell Lake was surveyed twice (1980 and 1992) and moderate numbers of Lake Trout were sampled (n=9). This lake is in the BWCAW and despite limited monitoring data from Powell Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Rabbit Lake (38-0214-00): The current Class 2A designation for Rabbit Lake was assigned to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Rabbit Lake was surveyed once in 1980 and a moderate number of Lake Trout (n=21) were sampled. This lake is in the BWCAW and despite the limited monitoring data from this lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Raven Lake (38-0113-00): The current Class 2A designation for Raven Lake was assigned to protect Lake Trout and it is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Raven Lake was surveyed once in 1975 and a moderate number of Lake Trout (n=13) were sampled. This lake is in the BWCAW and despite the limited monitoring data from this lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Red Rock Lake (16-0793-00): The current Class 2A designation for Red Rock Lake was assigned to protect Lake Trout and it is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout have been historically stocked in this lake, but it is not known if Lake Trout are native or sustainable in this lake. A single Lake Trout was sampled in 1998 which corresponds to the last year Lake Trout were stocked in Red Rock Lake. Three other MNDNR fisheries surveys did not collect any Lake Trout. Therefore, it is not appropriate to retain protections for Lake Trout in Red Rock Lake. However, in most fisheries surveys, Cisco and Lake Whitefish were sampled indicating that this lake supports natural populations of these coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Rog Lake (16-0765-00): Rog Lake is currently designated Class 2A by the MPCA for the protection of stream trout. However, management of Brook Trout in Rog Lake was discontinued due to the introduction of Smallmouth Bass. Despite the cessation of stream trout management, Rog Lake is still a MNDNR designated trout lake (Minn. R. 6264.0050). This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Sand Point Lake (69-0617-00): The current Class 2A designation for Sand Point Lake was assigned to protect stream trout although it is not designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "Minnesota-Ontario boundary potential lake trout lake" in Minnesota Department of Conservation (1967) which notes that Lake Trout are native to this lake. There have been MNDNR fisheries surveys conducted almost every year since 1982 on Sand Point Lake, but Lake Trout have never been sampled. However, these surveys have demonstrated that that this lake supports natural populations of Lake Whitefish and Cisco. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Shagawa Lake (69-0069-00): Shagawa Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Numerous MNDNR fisheries surveys have demonstrated that Shagawa Lake supports a population of Cisco. In fisheries surveys in 1966 and 1967, 5 fish were identified as Lake Whitefish, but due to their small size, these fish were possibly misidentified. In addition, Shagawa Lake is connected to Fall[23] (38-0811-00) and Burntside (69-0118-00) lakes which means that if the fish collected in the 1960s were Lake Whitefish, they may have been transient. As a result, it is reasonable to designate Shagawa Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Spoon Lake (38-0388-00): The current Class 2A designation for Spoon Lake was assigned to protect stream trout; however, this lake is not currently designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that dissolved oxygen conditions are "doubtful." A single fisheries survey in 1972 included a single fish identified as a Cisco, but this fish was possibly misidentified. In 2015, a MNDNR gill net survey sampled 58 Lake Whitefish indicating that Spoon Lake supports a population of Lake Whitefish. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Lake Whitefish (Class 2Ag [LKW]).

Spring Lake (69-0761-00): Spring Lake is currently designated Class 2A to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are not considered to be native but were stocked from 1955-2019. Lake Trout had poor survival which was attributed to competition with Lake Whitefish and not water quality issues. As a result, stocking of Lake Trout was discontinued in Spring Lake. All nine MNDNR fisheries surveys did sample Cisco and Lake Whitefish indicating that this lake supports natural populations of these coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is currently designated as a Lake Trout lake and is outside the BWCAW and Voyageurs National Park. As a result, the removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) for Spring Lake.

Steamhaul Lake (38-0570-00): The current Class 2A designation for Steamhaul Lake was assigned to protect stream trout. Steamhaul Lake is a designated MNDNR trout lake (Minn. R. 6264.0050), but it is not actively managed by the MNDNR because there is no reasonable public access. This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained unless the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Steep Lake (69-0475-00): Steep Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Steep Lake was surveyed twice (1974 and 2018) and low numbers of Cisco were sampled (n=6). However, Cisco were sampled in both fisheries surveys which indicates the presence of a possible population of this species. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate the Steep Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Strup Lake (38-0360-00): Strup Lake is currently designated Class 2A to protect Lake Trout and it is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Strup Lake was surveyed once in 1978 and a moderate number of Lake Trout (n=8) were sampled. This lake is in the BWCAW and despite limited monitoring data for Strup Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Sucker Lake (38-0530-00): Sucker Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Twelve MNDNR fisheries surveys have been conducted on Sucker Lake indicating that this lake supports a population of Cisco. Lake Whitefish were sampled in one of the twelve surveys with a total of 4 fish sampled, but these fish may have been transient from Basswood (38-0645-00) or the Moose Chain of Lakes. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Sucker Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Lake Three (38-0600-00): Lake Three is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. Lake Three was surveyed twice (1978 and 2017) and moderate numbers of Lake Whitefish were sampled (n=21) in 2017. In addition, Lake Whitefish were present in two additional MNDNR gill net surveys. Good numbers of Cisco were also sampled in these two surveys. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Lake Three a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Due to the limited monitoring data (i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation.

Thumb Lake (69-0352-00): The current Class 2A designation for Thumb Lake was assigned to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967), but fisheries surveys have not collected Lake Trout and there is no record of a Lake Trout population in this lake. A single MNDNR fisheries survey was conducted in 1980 and high numbers of Cisco (n=68) were sampled indicating that this lake supports a natural population of this coldwater fish species. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data

(i.e., two fisheries surveys), it is possible that additional information could result in a change to this designation. This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Toe Lake (69-0213-00): Toe Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey was conducted in 2002 and a moderate number of Cisco (n=9) were sampled indicating that this lake supports a natural population of this coldwater fish species. This lake is in the BWCAW and despite limited monitoring data, it is reasonable to designate Toe Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., one fisheries survey), it is possible that additional information could result in a change to this designation.

Topaz Lake (38-0172-00): The current Class 2A designation for Topaz Lake was assigned to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout are considered native to this lake, but Lake Trout have also been stocked. This lake was surveyed in 1973 and 5 Lake Trout were captured, but a subsequent survey in 2018 did not sample Lake Trout. Topaz Lake is connected to Amoeber (38-0227-00) and Cherry (38-0166-00) lakes which may be the source of the fish sampled in 1973. Additional information is needed before Topaz Lake should be designated for the protection of Lake Trout. Both MNDNR fisheries surveys sampled high numbers of Cisco indicating that this lake supports a natural population of this coldwater fish. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Town Lake (16-0458-00): The current Class 2A designation for Town Lake was assigned to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has "good" dissolved oxygen and temperature conditions. Town Lake was surveyed once in 1990 and a single Lake Trout was sampled. This fish is considered to represent the presence of a small, native population of Lake Trout in Town Lake. This lake is in the BWCAW and despite limited monitoring data from Town Lake, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Trip Lake (16-0451-00): Trip Lake is currently designated Class 2A by the MPCA to protect stream trout. However, management of stream trout in Trip Lake was discontinued due to low survivorship of stocked fish and a failure to meet management goals. However, this lake is still a designated trout lake by the MNDNR (Minn. R. 6264.0050). Trip Lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Vera Lake (38-0491-00): The current Class 2A designation for Vera Lake was assigned to protect stream trout, but this lake is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that dissolved oxygen conditions are "good." Lake Trout are not considered native to Vera Lake, but yearlings were stocked in 1977 because the 1972 survey indicated oxythermal conditions might be suitable for Lake Trout. Subsequent investigations indicated poor midsummer oxygen concentrations below 9 m and 5 fisheries surveys since 1972 did not sample Lake Trout. Most MNDNR fisheries surveys did sample Cisco indicating that this lake supports a natural population of this coldwater fish. Considering this information, it is reasonable to retain the Class 2Ag

classification for coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Class 2Bd designations

The following lakes will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the draft use designations are provided in Table 26 and additional details are provided following the table. For these lakes, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering the information below, it is reasonable to assign Class 2Bdg for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Rainy River - Headwaters watershed (09030001).

Table 26: List of draft Class 2Bd use designations for lakes in the Rainy River - Headwaters watershed (09030001) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Agamok*	38-0011-00	2.90					$2A^{SRT}$	2Bdg	No	2Bd
Arkose*	38-0382-00	1.47					$2A^{SRT}$	2Bdg	No	2Bd
Beartrack*	69-0480-00	2.65			U-1|4|1		$2A^{LAT}$	2Bdg	No	2Bd
Big Ruby (Warpaint)*	69-0333-00	1.36					$2A^{SRT}$	2Bdg	No	2Bd
Brandt (Everett)*	16-0600-00	1.05					$2A^{SRT}$	2Bdg	No	2Bd
Crab	16-0357-00	4.57			E-5|3|62		$2A^{SRT}$	2Bdg	No	2Bd
Marble*	38-0109-00	-					$2A^{SRT}$	2Bdg	No	2Bd
Mora*	16-0732-00	2.33					$2A^{LAT}$	2Bdg	No	2Bd
Tarry*	16-0731-00	1.23					$2A^{SRT}$	2Bdg	No	2Bd
Virgin*	16-0719-00	1.80	U-0|1|0				$2A^{SRT}$	2Bdg	No	2Bd
West Crab*	69-0297-00	4.93[24]					$2A^{SRT}$	2Bdg	No	2Bd

*** Partially or fully within the Boundary Waters Canoe Area Wilderness.**

[24] Depth (17.5') was estimated from MNDNR map to calculate geometry ratio.

Agamok Lake (38-0011-00): Agamok Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). No fishery surveys of this lake could be located, but there is no record of a population of Lake Trout or any other coldwater fish species in this lake. This lake is also relatively small (43 ha) and shallow (Z_{max} = 9 m) compared to other coldwater lakes which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Agamok Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Arkose Lake (38-0382-00): Arkose Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). There are no records of Lake Trout, Lake Whitefish, or Cisco populations in this lake and a 1979 survey only collected White Sucker (*Catostomus commersonii* [Lacepède, 1803]), Yellow Perch (*Perca flavescens* [Mitchill, 1814]), and Green Sunfish (*Lepomis cyanellus* Rafinesque, 1819). This lake is also small (8 ha) and shallow (Z_{max} = 6 m) compared to other coldwater lakes which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Arkose Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Beartrack Lake (69-0480-00): Beartrack Lake was designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that it has "good" dissolved oxygen conditions. Ohrid Trout (*Salmo letnica*) were stocked in 1965, but no stocked fish were recovered in subsequent sampling. There is no record of Lake Trout or Lake Whitefish populations in this lake and 5 surveys from 1965-2000 did not sample either of these species. Surveys on Beartrack Lake sampled White Sucker, Yellow Perch, Rock Bass (*Ambloplites rupestris* [Rafinesque, 1817]), and Green Sunfish. Cisco have also been sampled, but Beartrack Lake is connected to Eugene (69-0473-00) and Lac La Croix (69-0224-00) lakes and the single Cisco sampled in 1966 was likely transient. Considering this information, it is reasonable to assign Class 2Bdg to Beartrack Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Big Ruby Lake (69-0333-00): Big Ruby Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). No fishery surveys of this lake could be located, but there is no record of a population of any coldwater fish species. This lake is also small (17 ha) and relatively shallow (Z_{max} = 15 m) compared to other coldwater lakes which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Big Ruby Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation. The WID number for Big Ruby Lake listed in Minn. R. 7050.0470 is incorrect. This lake is currently listed as 16-0333-00 and as part of this rule revision the WID number will be corrected to 69-0333-00.

Brandt Lake (16-0600-00): Brandt Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that it has "marginal" dissolved oxygen conditions. There is no record of Lake Trout, Lake Whitefish, or Cisco populations in this lake and a 1979 survey only sampled White Sucker, Yellow Perch, and Northern Pike. The 1979 fisheries survey also indicated that oxythermal conditions in this lake were not suitable for Lake Trout. Considering this information, it is reasonable to assign Class 2Bdg to Brandt Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Crab Lake (16-0357-00): Crab Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). This report indicates that the maximum depth is 24 m; however, this is an error as the maximum depth for Crab Lake is 5 m. The geometry ratio in Crab Lake is greater than 4 and this lake is likely polymictic at least part of the summer. This lake was reportedly stocked between 1931 and 1944 with Lake Trout and stream trout in 1950, but six surveys from 1987 through 2023 failed to sample Lake Trout. In addition, Lake Whitefish and stream trout have not been sampled from this lake. Cisco have been periodically sampled in low numbers (1-2 fish per survey) from this lake (1987, 1997, 2023). The shallow depth and likely polymictic nature of this lake indicate that it is marginal for Cisco and the Cisco caught were likely transients from Loon Lake (16-0448-00). The draft coldwater standards for Cisco were not developed for polymictic lakes and even if there is a resident population of Cisco in Crab Lake, the application of dimictic lake standards would not be appropriate for this lake. Considering this information, it is reasonable to assign Class 2Bdg to Crab Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Marble Lake (38-0109-00): Marble Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). No fishery surveys of this lake could be located, but there is no record of a population of any coldwater fish species. This lake is also small (21 ha) compared to other coldwater lakes which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Marble Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Mora Lake (16-0732-00): Mora Lake was designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). There is no record of a Lake Trout population or a population of any coldwater species in this lake. Additionally, a fisheries survey determined that this lake has limited oxythermal habitat suitable to support Lake Trout. A MNDNR fisheries survey in 1983 sampled only White Sucker and Northern Pike. Mora Lake is relatively shallow (Z_{max} = 12 m) indicating that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Mora Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is in the BWCAW and therefore retains the prohibited ORVW designation.

Tarry Lake (16-0731-00): Tarry Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed for stream trout by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). No fishery surveys of

this lake could be located, but there is no record of a population of any coldwater fish species. This lake is also small (15 ha) compared to other coldwater lakes which indicates that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Tarry Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Virgin Lake (16-0719-00): Virgin Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). but there is limited fisheries and water quality data and no record of a population of any coldwater species in this lake. A MNDNR fisheries survey in 1980 sampled only large numbers of White Sucker. Virgin Lake is also relatively shallow (Z_{max} = 12 m) and small (23 ha) and therefore unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to Virgin Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

West Crab Lake (69-0297-00): West Crab Lake was designated Class 2A to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. West Crab Lake is effectively a bay of Crab Lake (69-0220-00) which is connected by a narrow channel. Three fisheries surveys from 1950 through 2001 in Crab Lake sampled Cisco. Crab Lake (69-0220-00) will be proposed for coldwater habitat designation to protect Cisco (Class 2A [TLC]). There are no fisheries survey data for West Crab Lake, but the lake morphology (GR = 4.9) indicates that this lake/basin is polymictic and unlikely to support a resident population of coldwater fish. This lake is also shallow (Z_{max} = 5 m) which demonstrated that it is unlikely to support a self-sustaining coldwater fish population. Considering this information, it is reasonable to assign Class 2Bdg to West Crab Lake for the protection of cool and warm waters also protected as a source of drinking water.

b. Vermilion River watershed (09030002)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 27 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Vermilion River watershed (09030002).

Table 27. List of draft Class 2A use confirmations and designations for lakes in the Vermilion River watershed (09030002) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Crane[#]	69-0616-00	2.43	E-1|17|1	U-6|12|8	P-17|1|938		$2A^{SRT}$	2Ag[LKW,TLC]	No	SM

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Elbow	69-0744-00	2.79		P-14|3|235	P-14|3|459		2B	2Ag[LKW,TLC]	No	2A
Kjostad	69-0748-00	2.07			P-15|0|1056		2B	2Ag[TLC]	No	2A
Little Trout*	69-0455-00	3.37			P-2|0|234		2Bd	2Ag[TLC]	No	2A
Mud	69-0275-00	3.07			P-8|0|409		2B	2Ag[TLC]	No	2A
Trout*	69-0498-00	2.47	P-16|7|168		P-19|4|11339		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Vermilion	69-0378-01,-02	4.36-4.91	E-0|54|0	P-14|40|76	P-39|15|7361		2Bd	2Ag[LKW,TLC]	No	2A
Winchester	69-0690-00	2.21	P-3|4|92		P-7|0|948		2B	2Ag[TLC,SRT]	No	2A

*** Partially or fully within the Boundary Waters Canoe Area Wilderness.**

 # Partially or fully within Voyageurs National Park.

Crane Lake (69-0616-00): The current Class 2A designation for Crane Lake was assigned to protect stream trout, but it is not currently designated (Minn. R. 6264.0050) or managed by the MNDNR for stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). There have been 18 MNDNR fisheries surveys and only a single Lake Trout was sampled (1991). The source of this Lake Trout is unknown, but Crane Lake is connected to lakes that support Lake Trout (e.g., Mukooda [69-0684-00]) or lakes that have been stocked with Lake Trout (e.g., Loon [69-0470-00]). There is no indication that this lake supports a population of Lake Trout, but these surveys did demonstrate that populations of Lake Whitefish and Cisco are present. This lake was reviewed in 1987 as part of review of ORVWs (State of Minnesota 1987) and it was determined that Crane Lake should not be designated as an ORVW to protect Lake Trout because the management of the lake is focused on the warm water fishery and the MNDNR had no plans to manage this lake for Lake Trout. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is not currently designated a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

Trout Lake (69-0498-00): Trout Lake is currently designated Class 2A to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that it has good dissolved oxygen. Lake Trout have been sampled in 16 of 23 MNDNR fisheries surveys and it is considered to support a healthy population of Lake Trout. The MNDNR recently stopped stocking Lake Trout due to the presence of a self-sustaining population. Considering this information, it is reasonable to retain the Class 2Ag designation for the protection of Lake Trout (Class 2Ag [LAT]).

Lake Vermilion (69-0378-01,-02): Lake Vermilion is currently designated Class 2Bd and is not designated for the protection of any coldwater fish species. Although the geometry ratio for Lake Vermilion is relatively high (4.36-4.91), this lake is large and complex, and the deeper basins have temperature profiles that indicate regular and consistent summer stratification. Numerous MNDNR fisheries surveys indicate that Lake Vermilion supports populations of Lake Whitefish and Cisco. Considering this information, it is reasonable to designate Lake Vermilion a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Water quality data for this lake are available from multiple basins and monitoring stations in this complex lake. Depth varies among the three basins delineated in the MPCA's waterbody

database (69-0378-01, -02, and -03). Both the East (69-0378-01) and West (69-0378-02) basins have areas that are more than 12 m deep and should have suitable habitat for coldwater fishes. The third basin, Pike Bay (69-0378-03), is shallow and should not be included in the coldwater designation.

Winchester Lake (69-0690-00): Winchester Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. All seven MNDNR fisheries surveys sampled good number of Cisco indicating that this lake supports a population of Cisco. The MNDNR stocked Lake Trout in Winchester Lake for 15 years but identified no natural reproduction. As a result, this lake does not support a natural or sustainable population of Lake Trout and the MNDNR intends to shift management of this lake to splake. Considering this information, it is reasonable to designate Winchester Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco and stream trout (Class 2Ag [TLC,SRT]).

c. Rainy River - Rainy Lake watershed (09030003)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 28 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Whitefish or Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Rainy River - Rainy Lake watershed (09030003).

Table 28. List of draft Class 2A use confirmations and designations for lakes in the Rainy River - Rainy Lake watershed (09030003) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Locator[#]	69-0936-00	1.71			P-3|5|40		2B	2Ag[TLC]	No	2A
Rainy[#]	69-0694-00	21.27	E-0|29|0	P-21|8|83	P-28|1|1148		2Bd	2Ag[LKW,TLC]	No	2A
War Club[#]	69-0937-00	1.96			P-4|3|59		2B	2Ag[TLC]	No	2A

[#] Partially or fully within Voyageurs National Park.

Rainy Lake (69-0694-00): Rainy Lake is currently designated Class 2Bd and it is not designated for the protection of any coldwater fish species. It is partially within Voyageurs National Park. It is not designated for the protection of Lake Trout and it is not listed in Minnesota Department of Conservation (1967) as a trout lake. Lake Trout were stocked from 1917-1944, but no Lake Trout have been sampled in 29 MNDNR fisheries surveys. There is no indication that this lake supports a population of Lake Trout, but MNDNR surveys did demonstrate that populations of Lake Whitefish and Cisco are present. Considering this information, it is reasonable to designate Rainy Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

d. Little Fork River watershed (09030005)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 29. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Whitefish or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Little Fork River watershed (09030005).

Table 29. List of draft Class 2A use confirmations and designations for lakes in the Little Fork River watershed (09030005) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Camp A (Camp Four, Wessman)	69-0788-00	1.68				BKT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Deepwater	69-0858-00	1.49				BNT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Dewey	69-0912-00	2.53			U-3|0|58		2B	2Ag[TLC]	No	2A
James (Jammer)	69-0734-00	1.62				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Leander	69-0796-00	2.3			U-3|0|29		2B	2Ag[TLC]	No	2A
Long	69-0859-01,-02	1.88-2.69			U-4|3|47		2B	2Ag[TLC]	No	2A
Pickerel	69-0934-00	1.30				RBT,SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Side	69-0933-00	3.70			P-9|0|620		2B	2Ag[TLC]	No	2A
South Sturgeon	31-0003-00	2.29			U-7|1|341		2B	2Ag[TLC]	No	2A
Sturgeon	69-0939-01	2.06		U-3|6|14	P-8|1|349		2B	2Ag[LKW,TLC]	No	2A
West Sturgeon	69-0939-03	2.44			P-5|0|113		2B	2Ag[TLC]	No	2A

e. Big Fork River watershed (09030006)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 30 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or are managed for

coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Big Fork River watershed (09030006).

Table 30. List of draft Class 2A use confirmations and designations for lakes in the Big Fork River watershed (09030006) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Batson	31-0704-00	1.7			P-3|0|25		2B	2Ag[TLC]	No	2A
Bello	31-0726-00	2.14			P-7|0|240		2B	2Ag[TLC]	No	2A
Big Too Much	31-0793-00	1.12			P-8|0|970		2B	2Ae[TLC]	No	2A
Caribou	31-0620-00	0.68	P-9|0|189				$2A^{LAT}$	2Ag[LAT]	No	SC
Clubhouse	31-0540-00	1.02			P-5|1|181		2B	2Ae[TLC]	No	2A
Deer	31-0334-00	3.42			P-11|1|223		2B	2Ag[TLC]	No	2A
East	31-0460-00	1.49			U-2|0|103		2B	2Ag[TLC]	No	2A
Elizabeth	31-0490-00	2.31			U-2|0|10		2B	2Ag[TLC]	No	2A
Erskine	31-0311-00	1.15				RBT,SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Five Island	31-0183-00	3.09			U-3|1|44		2B	2Ag[TLC]	No	2A
Fox	31-0463-00	1.40			U-2|0|158		2B	2Ag[TLC]	No	2A
Grave	31-0624-01,-02	3.17			P-8|1|168		2B	2Ae[TLC]	No	2A
Gunn	31-0480-00	2.95			P-6|0|203		2B	2Ag[TLC]	No	2A
Gunn	31-0452-00	1.12			U-1|0|21		2B	2Ag[TLC]	No	2A
Hatch	31-0771-00	1.15		P-6|1|49	P-7|0|536		2B	2Ag[LKW,TLC]	No	2A
Highland	31-0481-00	2.19			P-3|0|39		2B	2Ag[TLC]	No	2A
Horseshoe	31-0466-00	1.54			P-3|0|13		2B	2Ag[TLC]	No	2A
Jack the Horse	31-0657-01,-02	1.86-2.61			U-5|0|380		2B	2Ag[TLC]	No	2A
Jessie	31-0786-00	4.03	E-0|13|0		P-13|0|991		2B	2Ag[TLC]	No	2A
Johnson	31-0687-00	2.17		M-1|10|5	P-10|1|206		2B	2Ag[TLC]	No	2A
Larson	31-0317-00	0.54				SPT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Little Bowstring	31-0758-00	3.34			P-8|1|68		2B	2Ag[TLC]	No	2A
Little Jessie	31-0784-00	2.66			P-9|0|807		2B	2Ag[TLC]	No	2A
Little North Star	31-0665-00	1.65			P-4|1|16		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Long	31-0781-00	1.20			U-3|0|177		2B	2Ag[TLC]	No	2A
Maple	31-0773-00	2.65			P-7|0|198		2B	2Ag[TLC]	No	2A
North Star	31-0653-00	1.57			P-11|0|585		2B	2Ae[TLC]	No	2A
Pickerel	31-0339-00	1.46			P-11|1|408		2B	2Ag[TLC]	No	2A
Poplar	31-0196-00	1.71			U-3|0|41		2B	2Ag[TLC]	No	2A
Ruby	31-0422-00	1.16			U-10|1|132		2B	2Ag[TLC]	No	2A
Slauson	31-0502-00	2.11			U-2|0|26		2B	2Ag[TLC]	No	2A
Spring	31-0789-00	2.46			U-5|0|83		2B	2Ag[TLC]	No	2A
Turtle	31-0725-00	1.29	E-0|12|0	P-9|3|94	P-12|0|896		2B	2Ae[LKW,TLC]	No	2A
Unnamed (Nickel, Nichols)	31-0470-00	1.36				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Whitefish	31-0843-00	2.43			P-8|0|199		2B	2Ag[TLC]	No	2A

Gunn Lake (31-0452-00): Gunn Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Gunn Lake is in a remote area and there is limited fisheries information. A single MNDNR fisheries survey was conducted in 1982 and a moderate number of Cisco (n=21) were sampled indicating that this lake supports a natural population of this coldwater fish species. Although only a single fisheries survey is available, much of the watershed is undeveloped. Considering this information, it is reasonable to designate Gunn Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for and Cisco (Class 2Ag [TLC]). Due to the limited monitoring data (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Jessie Lake (31-0786-00): Jessie Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. It is not listed in Minnesota Department of Conservation (1967) as a trout lake. Lake Trout were stocked from 1912-1945, but no Lake Trout have been sampled in 13 MNDNR fisheries surveys. There is no indication that this lake supports a population of Lake Trout, but MNDNR surveys did demonstrate that a population of Cisco are present. Cisco were sampled in all thirteen MNDNR fisheries surveys. Considering this information, it is reasonable to designate Jessie Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Little Bowstring Lake (31-0758-00): Little Bowstring Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in eight of nine MNDNR fisheries surveys indicating that a population of Cisco are present. Considering this information, it is reasonable to designate Little Bowstring Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Turtle Lake (31-0725-00): Turtle Lake is currently designated Class 2B. It is not designated for the protection of Lake Trout and is not listed in Minnesota Department of Conservation (1967) as a trout lake. Lake Trout were stocked from 1916-1945, but no Lake Trout have been sampled in 12 MNDNR fisheries surveys. There is no indication that this lake supports a population of Lake Trout, but MNDNR surveys did demonstrate that populations of Lake Whitefish and Cisco are present. Considering this information, it is reasonable to designate Turtle Lake a Class 2Ae for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ae [LKW,TLC]). Documentation for the Exceptional Use designation is provided in MPCA (2024c).

Unnamed (Nickel, Nichols) Lake (31-0470-00): The current Class 2A designation for this unnamed lake was assigned to protect stream trout. Management of Brown Trout in this unnamed (Nickel, Nichols) lake was discontinued although the lake is still a designated trout lake by the MNDNR (Minn. R. 6264.0050). This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Whitefish Lake (31-0843-00): Whitefish Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in all eight MNDNR fisheries surveys on this lake indicating that a population of Cisco are present. Considering this information, it is reasonable to designate Whitefish Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

f. Rapid River watershed (09030007)

No draft use designations or confirmations

g. Rainy River - Lower watershed (09030008)

No draft use designations or confirmations

h. Lake of the Woods watershed (09030009)

No draft use designations or confirmations

3. Red River of the North basin

a. Bois de Sioux River watershed (09020101)

No draft use designations or confirmations

b. Mustinka River watershed (09020102)

No draft use designations or confirmations

c. Otter Tail River watershed (09020103)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 31 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Whitefish or Cisco or the lakes are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Otter Tail River watershed (09020103).

Table 31. List of draft Class 2A use confirmations and designations for lakes in the Otter Tail River watershed (09020103) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Acorn	03-0258-00	1.65			U-2|8|83		2B	2Ag[TLC]	No	2A
Annie Battle	56-0241-00	2.22			U-3|5|27		2B	2Ag[TLC]	No	2A
Bass	56-0722-00	1.60				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bass	56-0770-00	2.12			U-1|0|6		2B	2Ag[TLC]	No	2A
Big Pine	56-0130-00	2.85			P-14|0|361		2B	2Ag[TLC]	No	2A
Clitherall	56-0238-00	2.68			P-11|2|170		2B	2Ag[TLC]	No	2A
Crystal	56-0749-00	2.91			P-9|3|274		2B	2Ag[TLC]	No	2A
Dead	56-0383-00	3.74			P-14|0|275		2B	2Ag[TLC]	No	2A
Detroit	03-0381-00	2.37			U-9|5|143		2B	2Ag[TLC]	No	2A
East Battle	56-0138-00	2.00		E-1|12|1	P-13|0|201		2B	2Ag[TLC]	No	2A
East Loon	56-0523-00	1.40			P-9|0|311		2B	2Ag[TLC]	No	2A
Eunice	03-0503-00	3.82			P-8|2|50		2B	2Ag[TLC]	No	2A
Fish	56-0768-00	1.55			U-6|0|165		2B	2Ag[TLC]	No	2A
Franklin	56-0759-00	3.13			P-10|1|230		2B	2Ag[TLC]	No	2A
Hanson	03-0177-00	2.11				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Jewett	56-0877-00	1.80			P-12|2|297		2B	2Ag[TLC]	No	2A
Little Floyd	03-0386-00	3.11			P-11|0|120		2B	2Ag[TLC]	No	2A
Little McDonald	56-0328-00	1.43			P-1|10|5		2B	2Ag[TLC]	No	2A
Little Pine	56-0142-00	2.26			P-13|1|861		2B	2Ag[TLC]	No	2A
Lizzie (north portion)	56-0760-01	2.61			P-13|2|230		2B	2Ag[TLC]	No	2A
Long	56-0388-00	1.23			P-10|1|107		2B	2Ag[TLC]	No	2A
Long	56-0784-00	1.87			P-6|4|24		2B	2Ag[TLC]	No	2A
Long	03-0383-00	1.92			P-12|1|221		2B	2Ag[TLC]	No	2A
Marion	56-0243-00	2.76			P-13|0|242		2B	2Ag[TLC]	No	2A
Meadow	03-0371-00	1.04			P-8|2|711	NA-H|N|U	2B	2Ag[TLC]	No	2A
Molly Stark	56-0303-00	1.89		U-1|7|1	P-7|1|60		2B	2Ag[TLC]	No	2A
Murphy	56-0229-00	3.65			U-5|0|110		2B	2Ag[TLC]	No	2A
Otter Tail	56-0242-00	2.37		E-0|21|0	P-21|0|3301		2B	2Ag[TLC]	No	2A
Otter Tail River (Red River)	56-0711-00	2.04			U-3|3|11		2B	2Ag[TLC]	No	2A
Paul	56-0335-00	1.38			P-1|7|14		2B	2Ag[TLC]	No	2A
Pebble	56-0829-00	1.54			P-6|3|103		2B	2Ag[TLC]	No	2A
Pelican	56-0786-00	3.24			P-14|0|133		2B	2Ag[TLC]	No	2A
Pickerel	56-0475-00	1.74			P-8|3|124		2B	2Ag[TLC]	No	2A
Rose	56-0360-00	1.12			P-4|7|24		2B	2Ag[TLC]	No	2A
Scalp	56-0358-00	1.15			P-4|5|5		2B	2Ag[TLC]	No	2A
Six	56-0369-00	0.69			U-3|5|34		2B	2Ag[TLC]	No	2A
South Lida	56-0747-02	2.87			P-13|1|263		2B	2Ag[TLC]	No	2A
Star	56-0385-00	2.26			P-11|4|70		2B	2Ag[TLC]	No	2A
Stuart	56-0191-01	2.73			U-11|2|118		2B	2Ag[TLC]	No	2A
Sybil	56-0387-00	1.79			P-7|4|13		2B	2Ag[TLC]	No	2A
West Battle	56-0239-00	2.09		U-2|12|9	U-13|1|338		2B	2Ag[LKW,TLC]	No	2A
Wimer	56-0355-00	1.85			U-4|0|24		2B	2Ag[TLC]	No	2A

Little McDonald Lake (56-0328-00): Little McDonald Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries surveys using gill nets sampled 5 Cisco in 1959, but 10 other surveys did not detect Cisco. A fisheries survey using vertical gill nets was conducted in 2020 and a high number of Cisco were sampled (n=376) indicating that this lake supports a population of Cisco. Considering this information, it is reasonable to designate Little McDonald Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Meadow Lake (03-0371-00): Meadow Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. This lake was historically managed for stream trout, but it is no longer managed for stream trout nor is it a designated stream trout lake (Minn. R. 6264.0050). However, ten MNDNR fisheries surveys have been conducted which indicate that this lake supports a population of Cisco. Considering this information, it is reasonable to designate Meadow Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Molly Stark Lake (56-0303-00): Molly Stark Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Seven MNDNR fisheries surveys conducted on Molly Stark Lake have sampled Cisco indicating that this lake supports a population of Cisco. A single Lake Whitefish was sampled in one of the eight surveys, but this fish may have been transient from West Battle Lake (56-0239-00). At this time, this lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Molly Stark Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Paul (56-0335-00): Paul Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey using gill nets sampled 14 Cisco in 2020, but 7 other surveys did not detect Cisco. A fisheries survey using vertical gill nets was conducted in 2021 and 31 Cisco were sampled indicating that this lake supports a population of Cisco. Considering this information, it is reasonable to designate Paul Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Scalp Lake (56-0358-00): Scalp Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Four MNDNR fisheries surveys using gill nets sampled a total of 5 Cisco and five surveys did not detect Cisco. A fisheries survey using vertical gill nets was conducted in 2020 and a high number of Cisco were sampled (n=59) indicating that this lake supports a population of Cisco. Considering this information, it is reasonable to designate Scalp Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Stuart Lake (56-0191-01): Stuart Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco have been routinely sampled (11 of 13 surveys) in the main basin (56-0191-01). Considering this information, it is reasonable to designate Stuart Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Stuart Lake (Little West Bay) (56-0191-02) is shallow (Z_{max} ≈ 6 m) with a small surface area (19 ha) and is unlikely to support coldwater fishes during the period of maximum oxythermal stress. A small number of Cisco have been collected in Little West Bay, but these fish only represent a small fraction of the total cisco catch. As a result, 56-0191-02 will not be included in the coldwater habitat designation.

West Battle Lake (56-0239-00): West Battle Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Fourteen MNDNR fisheries surveys using standard gill nets have been conducted and Cisco were present in thirteen of these surveys. Lake Whitefish were present in two MNDNR fisheries surveys (n=9). In addition, Lake Whitefish were present in a 1993 MNDNR fall electrofishing survey. Considering this information, it is reasonable to designate West Battle Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Class 2Bd designations

The following lake will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the draft use designation is provided in Table 32 and additional details are provided following the table. For this lake, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering the information below, it is reasonable to assign Class 2Bdg to this lake for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Otter Tail River watershed (09020103).

Table 32: List of draft Class 2Bd use designations for lakes in the Otter Tail River watershed (09020103) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
East Twin (Little Twin)	03-0362-00	0.66					$2A^{SRT}$	2Bdg	No	2Bd

East Twin Lake (03-0362-00): East Twin Lake is currently designated Class 2A, but there is no indication in the MPCA's waterbody database regarding why this lake was originally designated for coldwater habitat. Presumably it was designated for the protection for stream trout, but it is not designated by the MNDNR as a stream trout lake (Minn. R. 6264.0050) nor is it managed for stream trout. As a result, evidence indicates that East Twin Lake was erroneously designated as Class 2A. A 1966 survey sampled only bullheads and the MNDNR's ecological classification for this lake is "Bullhead (occasional winterkill)." The 1966 MNDNR survey indicated that this lake could be managed for stream trout if winter dissolved oxygen conditions were suitable. However, there is no evidence that any attempt was made to stock or manage this lake for stream trout. This lake is also small (4 ha) which indicates that it is unlikely to support a self-sustaining population of coldwater fish species. Considering this information, it is reasonable to assign Class 2Bdg to East Twin Lake for the protection of cool and warm waters also protected as a source of drinking water.

d. Upper Red River of the North watershed (09020104)

No draft use designations or confirmations

e. Buffalo River watershed (09020106)

Class 2A confirmations and designations

The following lake is considered for designation as coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting this use designation is provided in Table 33. Available evidence demonstrates that this lake supports or should support a naturally reproducing population of Cisco. The use designation for this lake will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Buffalo River watershed (09020106).

Table 33. List of draft Class 2A use confirmations and designations for lakes in the Buffalo River watershed (09020106) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Buffalo	03-0350-00	3.17			P-10|0|364		2B	2Ag[TLC]	No	2A

f. Red River of the North - Marsh River watershed (09020107)

No draft use designations or confirmations

g. Wild Rice River watershed (09020108)

Class 2A confirmations and designations

The following lake will be confirmed for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting this use designation is provided in Table 34. This lake is currently managed for coldwater fish through stocking. The use designation for this lake will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Wild Rice River Watershed (09020108).

Table 34. List of draft Class 2A use confirmations and designations for lakes in the Wild Rice River Watershed (09020108) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Island (Wapatus)	15-0127-00	1.34				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

h. Red River of the North - Sandhill River watershed (09020301)

No draft use designations or confirmations

i. Upper/Lower Red Lake watershed (09020302)

No draft use designations or confirmations

j. Red Lake River watershed (09020303)

No draft use designations or confirmations

k. Thief River watershed (09020304)

No draft use designations or confirmations

l. Clearwater River watershed (09020305)

Class 2A confirmations and designations

The following lakes will be confirmed for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 35 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco or are managed for stream trout. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Clearwater River watershed (09020305).

Table 35. List of draft Class 2A use confirmations and designations for lakes in the Clearwater River watershed (09020305) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Buzzle	04-0297-00	1.19			U-2|0|113		2B	2Ag[TLC]	No	2A
Clearwater	04-0343-00	2.26			P-9|1|451		2B	2Ag[TLC]	No	2A
Deep	15-0090-00	0.89			E-3|6|25	RBT-C|Y|U	2B	2Ag[SRT]	No	2A

Buzzle Lake (04-0297-00): Buzzle Lake is currently designated Class 2B and is not designated for the protection of any coldwater fish species. The current status of Cisco in Buzzle Lake is uncertain due to a lack of recent fishery surveys and a lack of surveys using deep-set gill nets. However, a survey in 1970 sampled 112 Cisco and a single Cisco was sampled in 1986. The abundance of fish in these surveys may not reflect the actual population sizes in Buzzle Lake because the lake is difficult to survey due to steep drop offs in the lake margins and the 1986 survey only used two gill nets. It is likely that the Cisco population has persisted in Buzzle Lake, but additional sampling would be needed to confirm the status of this population. Regardless, the 1970 and 1986 surveys demonstrate that Cisco habitat is likely an existing use for Buzzle Lake. Considering this information, it is reasonable to designate Buzzle Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Deep Lake (15-0090-00): Deep Lake is currently designated Class 2B, but it is stocked with Rainbow Trout. It is not a designated by the MNDNR as a trout lake (Minn. R. 6264.0050), but it is reasonable to assign the Class 2A classification assigned to coldwater aquatic life and habitat. Three MNDNR fisheries surveys sampled Cisco in the 1980s and 1990s which were likely the result of a stocking of fish in 1974. However, no Cisco have been captured since 1996 in three surveys (2005, 2012, and 2017). Anglers have also not reported catching Cisco in this lake despite heavy fishing pressure. It is likely that the introduced population of Cisco is no longer extant and given that stocking was unable to establish a self-sustaining population it is not appropriate to designate Deep Lake for the protection of Cisco at this time. Considering this information, it is reasonable to designate Deep Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

m. Red River of the North - Grand Marais Creek watershed (09020306)

No draft use designations or confirmations

n. Snake River watershed (09020309)

No draft use designations or confirmations

o. Red River of the North - Tamarac River watershed (09020311)

No draft use designations or confirmations

p. Two Rivers watershed (09020312)

No draft use designations or confirmations

q. Roseau River watershed (09020314)

No draft use designations or confirmations

4. Upper Mississippi River basin

a. Mississippi River - Headwaters watershed (07010101)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 36 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Whitefish or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River - Headwaters watershed (07010101).

Table 36. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River - Headwaters watershed (07010101) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Bass	31-0576-00	4.70			P-9|0|288		2B	2Ag[TLC]	No	2A
Beltrami	04-0135-00	2.71			P-10|0|275		2B	2Ag[TLC]	No	2A
Bemidji (main lake)	04-0130-02	3.10	E-0|11|0	U-5|6|27	P-11|0|1298		2B	2Ag[LKW,TLC]	No	2A
Benjamin	04-0033-00	0.49				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	No	SC
Big LaSalle	15-0001-00	2.13			P-4|1|16		2B	2Ag[TLC]	No	2A
Blacksmith	29-0275-00	1.46				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Chase	31-0749-00	1.05			P-7|2|268		2B	2Ag[TLC]	No	2A
Deer	31-0719-00	2.09	E-0|10|0	P-8|2|46	P-8|2|394		2B	2Ag[LKW,TLC]	No	2A
Deer	04-0230-00	2.58			P-10|2|231		2B	2Ag[TLC]	No	2A
Elk	15-0010-00	1.14	E-0|10|0		P-10|0|655		2B	2Ag[TLC]	No	2A
Gilstad	04-0024-00	1.89		M-1|8|4	U-7|2|152		2B	2Ag[TLC]	No	2A
Grant	04-0217-00	1.07			P-7|0|537		2B	2Ag[TLC]	No	2A
Itasca	15-0016-00	3.32	E-0|12|0		P-12|0|262		2B	2Ag[TLC]	No	2A
Jay Gould	31-0565-00	3.59		U-2|6|2	P-7|1|46		2B	2Ag[TLC]	No	2A
LaSalle	29-0309-00	0.48			P-2|1|5		$2A^{SRT}$	2Ag[TLC]	No	SM
Leighton	31-0739-00	1.62		U-2|3|5	U-4|1|265		2B	2Ag[TLC]	No	2A
Little Bass	31-0575-00	1.50			P-6|1|138		2B	2Ag[TLC]	No	2A
Little Jay Gould	31-0566-00	1.63			P-3|1|280		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Long	15-0057-00	1.14				RBT-C|N|U	2B	2Ag[SRT]	No	2A
Loon	31-0579-00	1.36			U-1|0|67		2B	2Ag[TLC]	No	2A
Loon	31-0571-00	1.47			P-9|0|538		2B	2Ag[TLC]	No	2A
Lucky	31-0603-00	1.15				BNT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Marquette	04-0142-00	2.44	E-0|4|0	P-1|3|1	P-4|0|163		2B	2Ag[TLC]	No	2A
Moose	31-0722-00	2.56			P-17|0|1680		2B	2Ag[TLC]	No	2A
Movil	04-0152-00	2.77			P-10|0|258		2B	2Ag[TLC]	No	2A
Newman (Putman)	29-0237-00	1.06			E-1|14|105	RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Pimushe	04-0032-00	3.86		U-1|8|3	P-9|0|223		2B	2Ag[TLC]	No	2A
Plantagenet	29-0156-00	2.85		U-1|8|1	P-9|0|407		2B	2Ag[TLC]	No	2A
Pokegama	31-0532-01, -02	2.01-2.05	U-0|10|0	U-6|4|9	P-9|1|368		$2A^{LAT}$	2Ag[TLC]	No	SM
Rabideau	04-0034-00	1.18			P-6|3|20		2B	2Ag[TLC]	No	2A
Rice	31-0717-00	2.07			P-10|0|510		2B	2Ag[TLC]	No	2A
Siseebakwet	31-0554-00	1.47			P-10|2|206		2B	2Ag[TLC]	No	2A
Spearhead	29-0239-00	1.17			P-4|0|122		2B	2Ag[TLC]	No	2A
Tioga Mine Pit	31-0946-00	0.31				RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Turtle	04-0159-00	3.67	E-0|11|0		P-11|0|552		2B	2Ag[TLC]	No	2A
Turtle River	04-0111-00	2.68		U-2|8|2	P-10|0|649		2B	2Ag[TLC]	No	2A
Wolf	04-0079-00	2.63		U-5|6|7	P-11|0|802		2B	2Ag[TLC]	No	2A

Lake Bemidji (main lake) (04-0130-02): Lake Bemidji is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eleven MNDNR fisheries surveys have been conducted on Lake Bemidji which demonstrate that this lake supports populations of Lake Whitefish and Cisco. Lake Trout were stocked in 1909, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Lake Bemidji a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Deer Lake (31-0719-00): Deer Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eight of the ten MNDNR fisheries surveys conducted on Deer Lake sampled Cisco and Lake Whitefish indicating that this lake supports populations of Lake Whitefish and Cisco. Lake Trout were stocked from 1913-45, but this species has not been present in any MNDNR fisheries survey. Considering this information, it

is reasonable to designate Deer Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Elk Lake (15-0010-00): Elk Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Ten MNDNR fisheries surveys have been conducted on Elk Lake and all surveys sampled Cisco indicating that this lake supports a population Cisco. Lake Trout were stocked in 1911, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Elk Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Gilstad Lake (04-0024-00): Gilstad Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Nine MNDNR fisheries surveys have been conducted and Cisco were present in eight of these surveys. In the single survey (1977) where Cisco were absent, four Lake Whitefish were identified. This is the only survey from Gilstad Lake which included fish identified as Lake Whitefish, indicating that these fish were possibly misidentified. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Gilstad Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Lake Itasca (15-0016-00): Lake Itasca is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Twelve MNDNR fisheries surveys have been conducted on Lake Itasca and all sampled Cisco indicating that this lake supports a population of Cisco. Lake Trout were stocked in 1912, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Lake Itasca a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Jay Gould Lake (31-0565-00): Jay Gould Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eight MNDNR fisheries surveys have been conducted on Jay Gould Lake and they indicate that this lake supports a population of Cisco. Lake Whitefish were sampled in two of the eight surveys with a total of 2 fish sampled. Jay Gould Lake is broadly connected to the Mississippi River and these Lake Whitefish may have been transient. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Jay Gould Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

LaSalle Lake (29-0309-00): The current Class 2A designation for LaSalle Lake was assigned to protect stream trout, but it is not a designated by the MNDNR as a stream trout lake (Minn. R. 6264.0050) nor is it managed for stream trout. Small numbers of Cisco (n=5) were present in two MNDNR fisheries surveys. In addition, a high number of Cisco (n=126) were sampled in a 2017 MNDNR vertical gill net survey. This information indicates that LaSalle Lake supports a population of Cisco. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat. The designation for LaSalle Lake will be based on the protection of Cisco and will be designated Class 2Ag [TLC].

Leighton Lake (31-0739-00): Leighton Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Five MNDNR fisheries surveys have been conducted on Leighton Lake and they indicate that this lake supports a population of Cisco. Lake Whitefish were sampled in two of the surveys with a total of 5 fish sampled. Leighton Lake is connected to the Mississippi River and these Lake Whitefish may have been

transient. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Leighton Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Long Lake (15-0057-00): Long Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Although it is not a designated stream trout lake, it is managed for Rainbow Trout. Available information (geometry ratio = 1.14 and temperature profile) indicates that this lake is dimictic and would likely benefit from coldwater lake standards to protect trout during the summer. Considering this information, it is reasonable to designate Long Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Loon Lake (31-0579-00): Loon Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Loon Lake is in a remote area and there is limited fisheries information. A single MNDNR fisheries survey was conducted in 1980 and a high number of Cisco (n=67) were sampled indicating that this lake supports a natural population of this coldwater fish. Although only a single fisheries survey is available, much of the watershed is undeveloped. Considering this information, it is reasonable to designate Loon Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

Marquette Lake (04-0142-00): Marquette Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Four MNDNR fisheries surveys have been conducted on Marquette Lake and they indicate that this lake supports a population of Cisco. A single Lake Whitefish was sampled in one survey. Marquette Lake is connected to the Mississippi River, Schoolcraft River, and Lake Bemidji (04-0130-02) and this Lake Whitefish may have been transient. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Lake Trout were stocked in 1917, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Marquette Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Movil Lake (04-0152-00): Movil Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Ten MNDNR fisheries surveys have been conducted on Movil Lake and Cisco were present in all surveys indicating that this lake supports a population of Cisco. The summer average estimate of T_{DO3} (21.3 °C) for Movil Lake is near the draft criterion for this parameter despite MNDNR fisheries surveys consistently indicating the presence of a healthy population of Cisco. There is some disturbed land use (19.6%) in the watershed of this lake indicating possible impacts, but the watershed is largely intact. In addition, Movil Lake is connected to Turtle Lake (04-0159-00) so the Cisco population in Movil Lake may be supplemented from Turtle Lake. This lake has not been monitored by the MNDNR for macrophytes, but a 2011 MNDNR fish survey did determine that the cool/warm water fish community is healthy. Recreation suitability data were collected from Movil Lake from 2000-2019 on 226 days and there were no surveys with recreation suitability scores indicating poor conditions for swimming. Most recreation survey scores for Movil Lake indicated excellent conditions for recreation such as swimming. Summer average TP and chl-*a* was low (TP = 14 µg/L; chl-*a* = 5 µg/L) and Secchi depth (3.9 m) is also very good for this lake. Although T_{DO3} is near the draft criterion, aquatic life (i.e., Cisco and fish community) and recreation measures demonstrate that this lake meets beneficial use goals. The average T_{DO3} value is based on a relatively good dataset consisting of 5 years of data, but

additional sampling may indicate a need for an SSS. Although coldwater habitat is limited in this lake (i.e., narrow oxythermal layer) and fish may be supplemented from Turtle Lake (04-0159-00), the Cisco population in Movil Lake may be self-sustaining. Considering this information, it is reasonable to designate Movil Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Newman (Putman) Lake (29-0237-00): The current Class 2A designation for Newman Lake was assigned to protect stream trout and it is designated by the MNDNR as a stream trout lake (Minn. R. 6264.0050) and it is managed for Rainbow Trout. Cisco were stocked in this lake in 1977 and this species was sampled in high numbers in 1984. However, the lake was reclaimed in 1984 for the management of stream trout and the introduced population of Cisco was extirpated. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat. The designation for Newman Lake will be based on the protection of stream trout and will be designated Class 2Ag [SRT].

Pimushe Lake (04-0032-00): Pimushe Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Nine MNDNR fisheries surveys have been conducted on Pimushe Lake which indicate that this lake supports a population of Cisco. Lake Whitefish were sampled in one of the surveys with a total of 3 fish sampled, but these fish may have been transient from Cass Lake (04-0030-00) or the Turtle River. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected. Considering this information, it is reasonable to designate Pimushe Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Plantagenet Lake (29-0156-00): Plantagenet Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Nine MNDNR fisheries surveys have been conducted on Plantagenet Lake which indicate that this lake supports a population of Cisco. A single Lake Whitefish was sampled in one survey, but this fish may have been transient from the Schoolcraft River or Lake Bemidji (04-0130-02). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Plantagenet Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Pokegama Lake (31-0532-01,-02): Pokegama Lake is currently designated Class 2A to protect Lake Trout. It is listed as an “inland lake trout lake” in Minnesota Department of Conservation (1967) which also notes that the lake has an “adverse fish population.” Ten MNDNR fisheries surveys have been conducted on Pokegama Lake and they indicate that this lake supports a population of Cisco. Lake Whitefish were sampled in six of the surveys with a total of 9 fish sampled. Pokegama Lake is connected to the Mississippi River, catches of Lake Whitefish are variable, and catches largely consist of large individuals which indicate this species is transient. Due to low numbers of this fish species in samples and the possibility that these fish were transient; this lake will not be designated at this time for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Lake Trout were stocked in Pokegama Lake from 1909-1945 and are currently stocked opportunistically, but this species is not managed to support a long-term fishery. In addition, Lake Trout have not been present in any MNDNR fisheries surveys. Due to the lack of documented natural reproduction and management goals for Pokegama Lake, the Lake Trout designation will not be retained. Considering this information, it is reasonable to designate Pokegama Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). As a result, the removal of the Lake Trout designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) from Pokegama Lake.

Turtle Lake (04-0159-00): Turtle Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eleven MNDNR fisheries surveys have been conducted on Turtle Lake and Cisco were present in every survey indicating that this lake supports populations of Cisco. Lake Trout were stocked in 1911, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Turtle Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Turtle River Lake (04-0111-00): Turtle River Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Ten MNDNR fisheries surveys conducted on Turtle River Lake all sampled Cisco indicating that this lake supports a population of Cisco. Lake Whitefish were sampled in two of the surveys with a total of 2 fish sampled, but these fish may have been transient from Cass Lake (04-0030-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Turtle River Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Wolf Lake (04-0079-00): Wolf Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eleven MNDNR fisheries surveys conducted on Wolf Lake all sampled Cisco indicating that this lake supports a population of Cisco. Lake Whitefish were sampled in five of the surveys with a total of 7 fish sampled, but these fish may have been transient from Cass Lake (04-0030-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. Considering this information, it is reasonable to designate Wolf Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

b. Leech Lake River watershed (07010102)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 37 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Whitefish or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Leech Lake River watershed (07010102).

Table 37. List of draft Class 2A use confirmations and designations for lakes in the Leech Lake River watershed (07010102) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Baby	11-0283-00	1.97			P-11|0|494		2B	2Ag[TLC]	No	2A
Benedict	29-0048-00	1.34		P-2|9|2	P-11|0|532		$2A^{SRT}$	2Ag[TLC]	No	SM
Big Deep	11-0277-00	1.26			U-3|3|45		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Blackwater	11-0274-00	2.05			P-14|0|755		2B	2Ag[TLC]	No	2A
Boy	11-0143-00	4.52			P-12|0|543		2B	2Ag[TLC]	No	2A
Child	11-0263-00	3.70			U-5|4|25		2B	2Ag[TLC]	No	2A
Cooper	11-0163-00	1.27			U-2|0|104		2B	2Ag[TLC]	No	2A
Crappie	29-0127-00	0.74				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Diamond	11-0396-00	2.49				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Girl	11-0174-00	1.46			P-10|0|204		2B	2Ag[TLC]	No	2A
Hazel	11-0295-00	1.33				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Howard	11-0472-00	1.88			U-6|0|580		2B	2Ag[TLC]	No	2A
Inguadona	11-0120-01,-02	1.81-2.52			P-12|0|901		2B	2Ag[TLC]	No	2A
Kabekona	29-0075-00	1.38	E-0|12|0	P-2|10|13	P-12|0|1674		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Kid	11-0262-00	1.81			U-2|2|47		2B	2Ag[TLC]	No	2A
Leech	11-0203-01,-02, -03,-04	1.49-3.12		P-13|24|38	P-29|8|5101		2B	2Ag[LKW,TLC]	No	2A
Little Boy	11-0167-00	2.23			P-13|2|446		2B	2Ag[TLC]	No	2A
Long	11-0480-00	1.33			P-8|0|355		2B	2Ag[TLC]	No	2A
Man	11-0282-00	1.40			P-8|1|553		2B	2Ag[TLC]	No	2A
May	11-0482-00	1.78			U-6|2|38		2B	2Ag[TLC]	No	2A
McKeown	11-0261-00	2.53			U-2|1|17		2B	2Ag[TLC]	No	2A
Mule	11-0200-00	2.66			U-6|7|57		2B	2Ag[TLC]	No	2A
Pleasant	11-0383-00	2.09			P-12|2|136		2B	2Ag[TLC]	No	2A
Portage	11-0476-00	1.27			U-2|7|145		2B	2Ag[TLC]	No	2A
Shingobee	29-0043-00	2.42			U-2|0|15		2B	2Ag[TLC]	No	2A
Steamboat	11-0504-00*	1.82		P-3|9|3	U-8|4|598		2B	2Ag[TLC]	No	2A
Swift	11-0133-00	2.31			U-5|0|74		2B	2Ag[TLC]	No	2A
Teepee (Cranberry)	11-0312-00	1.85				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Ten Mile	11-0413-00	1.06		P-19|0|670	P-3|16|19		2B	2Ag[LKW,TLC]	No	2A
Upper Trelipe	11-0105-00	1.71			P-12|0|523		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Wabedo	11-0171-01,-02	1.38-2.56			P-13|0|1842		2B	2Ag[TLC]	No	2A

Benedict Lake (29-0048-00): The current Class 2A designation for Benedict Lake was assigned to protect stream trout, but it is not a designated stream trout lake (Minn. R. 6264.0050) nor is it managed for stream trout. It is listed as a "potential inland Lake Trout lake" in Minnesota Department of Conservation (1967). Lake Trout were stocked on an experimental basis in 1955, but test nettings did not capture any Lake Trout and all MNDNR fisheries surveys have failed to sample Lake Trout. Eleven MNDNR fisheries surveys have demonstrated that Benedict Lake supports a population of Cisco. A total of 2 Lake Whitefish were sampled in two of the fisheries surveys. Benedict Lake is connected to Leech Lake (11-0203-00) which indicates these 2 fish may been transient. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Benedict Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Kabekona Lake (29-0075-00): Kabekona Lake is currently designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Lake Trout were stocked periodically from 1911-2004, but the 12 MNDNR fisheries surveys conducted on Kabekona Lake have never sampled Lake Trout. However, fisheries survey data do indicate that this lake supports populations of Lake Whitefish and Cisco. Considering this information, it is reasonable to retain the Class 2Ag designation for coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). As a result, the removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) from Kabekona Lake.

Steamboat Lake (11-0504-00): Steamboat Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Twelve MNDNR fisheries surveys have been conducted and Cisco were present in eight of these surveys. Lake Whitefish were also sampled in 3 fisheries surveys for a total of 3 fish. Steamboat Lake is connected to Leech Lake (11-0203-00) which indicates these fish may have been transient. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Steamboat Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco only (Class 2Ag [TLC]).

c. Mississippi River – Grand Rapids watershed (07010103)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 38 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River – Grand Rapids watershed (07010103).

Table 38. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River – Grand Rapids watershed (07010103) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Antler	31-0349-00	1.14			P-7|0|115		2B	2Ag[TLC]	No	2A
Ball Bluff	01-0046-00	0.38			P-7|0|105		2B	2Ag[TLC]	No	2A
Balsam	31-0259-00	3.60			P-11|1|710		2B	2Ag[TLC]	No	2A
Barwise	31-0278-00	1.60			P-1|1|30		2B	2Ag[TLC]	No	2A
Bass	11-0069-00	1.77			P-7|0|313		2B	2Ag[TLC]	No	2A
Bass	01-0073-00	0.38			U-4|1|11		2B	2Ag[TLC]	No	2A
Bee Cee	31-0443-00	1.85				NA-H|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Big Sandy	01-0062-00	0.85		M-1|15|54	P-14|2|1255		2B	2Ag[TLC]	No	2A
Bluewater	31-0395-00	0.95	P-9|0|178		P-9|0|147		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Bray	31-0147-00	2.17			P-5|0|107		2B	2Ag[TLC]	No	2A
Crooked	31-0193-00	1.80		M-1|9|7	P-10|0|520		2B	2Ag[TLC]	No	2A
Cutaway	31-0429-00	1.89			U-2|0|64		2B	2Ag[TLC]	No	2A
Hale	31-0373-00	1.54			P-4|2|43		2B	2Ag[TLC]	No	2A
Hanson	31-0344-00	1.14			U-2|0|26		2B	2Ag[TLC]	No	2A
Hart	31-0020-00	2.01	E-0|4|0		U-4|0|415		2B	2Ag[TLC]	No	2A
Hartley	31-0154-00	2.16		U-2|7|12	U-6|3|72		2B	2Ag[LKW,TLC]	No	2A
Haskell	31-0945-00	1.44		M-1|1|9	P-1|1|128		2B	2Ag[TLC]	No	2A
Kremer	31-0645-00	0.89	E-0|9|0			BNT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Little Ball Bluff	01-0057-00	0.41			U-5|2|18		2B	2Ag[TLC]	No	2A
Little Thunder	11-0009-01,-02	1.06-1.40			P-3|2|19		2B	2Ag[TLC]	No	2A
Little Trout	31-0394-00	0.99	E-1|1|1		U-2|0|169		$2A^{LAT}$	2Ag[TLC]	No	SM
Little Wabana	31-0399-00	1.50			U-2|1|77		2B	2Ag[TLC]	No	2A
Loon	01-0024-00	0.91				BNT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Lower Balsam	31-0247-00	3.62			P-5|0|90		2B	2Ag[TLC]	No	2A
Lower Hanson	31-0239-00	1.00			U-1|0|68		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Moonshine (Little Moonshine)	31-0444-00	0.87				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Nashwauk	31-0192-00	1.75			U-3|0|481		2B	2Ag[TLC]	No	2A
North Twin	31-0190-00	2.47			U-4|2|98		2B	2Ag[TLC]	No	2A
No-ta-she-bun	31-0775-00	2.56			U-3|6|80		2B	2Ag[TLC]	No	2A
O'Reilly	31-0219-00	1.24			P-7|0|142		2B	2Ag[TLC]	No	2A
Ox Hide	31-0106-00	2.18			P-4|3|18		2B	2Ag[TLC]	No	2A
Prairie	69-0848-00	3.09			P-10|0|394		2B	2Ag[TLC]	No	2A
Round	01-0070-00	0.56			P-8|0|275		2B	2Ag[TLC]	No	2A
Shallow	31-0084-00	1.49			P-8|4|480		2B	2Ag[TLC]	No	2A
Shamrock	31-0218-00	1.28			P-6|0|50		2B	2Ag[TLC]	No	2A
Snaptail	31-0255-00	1.38			U-5|4|248		2B	2Ag[TLC]	No	2A
South Twin	31-0191-00	2.29			U-5|0|82		2B	2Ag[TLC]	No	2A
Swan	31-0067-02	2.73	E-0|14|0		P-13|1|1675		2B	2Ag[TLC]	No	2A
Taylor	01-0109-00	0.24			P-4|2|11	BKT, RBT-C|Y|U	$2A^{SRT}$	2Ag[TLC,SRT]	Yes	SM
Thunder	11-0062-00	1.95		U-4|4|4	P-8|0|720		2B	2Ag[TLC]	No	2A
Trout	31-0410-00	1.08	P-9|4|66		P-13|0|2858		$2A^{LAT}$	2Ag[LAT,TLC]	No	SM
Trout	31-0216-00	1.26	E-0|12|0	U-2|10|18	U-10|2|220		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Wabana	31-0392-00	1.56			P-9|1|523		$2A^{SRT}$	2Ag[TLC]	No	SM
Wasson	31-0281-00	1.76	E-0|4|0		U-2|2|19		2B	2Ag[TLC]	No	2A

Bee Cee Lake (31-0443-00): Bee Cee Lake is currently designated Class 2A to protect stream trout. Management of stream trout in Bee Cee Lake was discontinued although the lake is still a designated trout lake (Minn. R. 6264.0050). This lake is currently designated Class 2Ag and this use (Class 2Ag [SRT]) will be retained until the MNDNR removes this lake from the list of designated trout lakes or additional information indicates its removal is appropriate.

Big Sandy Lake (01-0062-00): Big Sandy Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Fourteen MNDNR fisheries surveys have sampled Cisco indicating that this lake supports a population of Cisco. Cisco were possibly misidentified as Lake Whitefish in 1982 as 54 Lake Whitefish and no Cisco were identified in this survey. The size of most of these fish were more typical of Cisco although one large specimen was observed and identified as a Lake Whitefish. However, Big Sandy Lake is connected to the Mississippi River and distantly to

Pokegama Lake (31-0532-01, -02) which could have been the source of this fish. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Big Sandy a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Big Sandy Lake is a large and complex lake with several bays, but suitable summer habitat for Cisco is largely in Bell Horn Bay. Cisco likely use the whole lake most of the year but require the refuge of Bell Horn Bay during the period of maximum oxythermal stress. As a result, assessment of Cisco habitat should be based only on monitoring from Bell Horn Bay to ensure an accurate measure of the condition of Cisco habitat in Big Sandy Lake.

Hart Lake (31-0020-00): Hart Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Four MNDNR fisheries surveys have been conducted on Hart Lake and Cisco were present in every survey indicating that this lake supports populations of Cisco. Lake Trout were stocked from 1913-1945, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Hart Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Haskell Lake (31-0945-00): Haskell Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Two MNDNR fisheries surveys have been conducted on this lake and a high number of Cisco (n=128) were present in the 2016 survey. No Lake Whitefish were sampled in 2016. A fisheries survey in 1972 collected 9 fish identified as Lake Whitefish, but no fish were identified as Cisco. These data indicate a possible misidentification as most or all of these fish may have been Cisco. Any Lake Whitefish present may have been transient as Hartley Lake is distantly connected to Crooked Lake (31-0193-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Hartley Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco only (Class 2Ag [TLC]).

Kremer Lake (31-0645-00): Kremer Lake is currently designated Class 2A to protection stream trout. This lake is currently managed (Brown and Rainbow Trout) and designated as a stream trout lake by the MNDNR (Minn. R. 6264.0050). Lake Trout were stocked in 1943, but this species has not been present in any of the nine MNDNR fisheries surveys conducted on this lake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Little Trout Lake (31-0394-00): Little Trout Lake is currently designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes the presence of "good" dissolved oxygen conditions. It was presumably listed as a Class 2A based on the 1967 report. A single Lake Trout was sampled in a 1981 MNDNR fisheries survey, but no trout were sampled in a subsequent survey. Little Trout Lake is connected to Trout Lake (31-0410-00) and the Lake Trout sampled in 1981 may have been transient. This lake will not be designated for the protection of Lake Trout until additional data can be collected to confirm the presence of a resident population of Lake Trout. However, both MNDNR fisheries surveys did sample Cisco indicating that this lake supports a population of this coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag designation for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). As a result, the removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) from Little Trout Lake.

Lower Hanson Lake (31-0239-00): Lower Hanson Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey was conducted in 1980 and a high number of Cisco (n=68) were sampled indicating that this lake supports a natural population of this coldwater fish. Considering this information, it is reasonable to designate Lower Hanson Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring (i.e., a single fisheries survey), it is possible that additional information could result in a change to this designation.

North Twin Lake (31-0190-00): North Twin Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Four of six MNDNR fisheries surveys sampled Cisco indicating that this lake supports a natural population of this coldwater fish. Considering this information, it is reasonable to designate North Twin Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Swan Lake (31-0067-02): Swan Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Fourteen MNDNR fisheries surveys have been conducted on Swan Lake and Cisco were present in thirteen of these surveys indicating that this lake supports a population of Cisco. Lake Trout were stocked from 1913-1945, but this species has not been present in any MNDNR fisheries survey. Considering this information, it is reasonable to designate Swan Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Swan Lake West Bay (31-0067-01) and Southwest Bay (31-0067-03) are shallow (Z_{max} < 6.1 m) and unlikely to support coldwater fishes during the period of maximum oxythermal stress. A small number of Cisco have been collected in West Bay, but these fish only represent a small fraction of the total Cisco catch. As a result, 31-0067-01 and 31-0067-03 will not be included with the coldwater habitat designation.

Thunder Lake (11-0062-00): Thunder Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eight MNDNR fisheries surveys have been conducted on this lake and Cisco were present in every survey. Lake Whitefish were sampled in four of these surveys with a total of 4 fish sampled. These Lake Whitefish may have been transient as Thunder Lake is distantly connected to Leech Lake (11-0203-00). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Thunder Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Trout Lake (31-0216-00): Trout Lake is currently designated Class 2A to protect Lake Trout. It is listed as an “inland lake trout lake” in Minnesota Department of Conservation (1967) which also notes the presence of an “adverse fish population.” Lake Trout were stocked in 1965, but this species has never been sampled in the 12 MNDNR fisheries surveys conducted on Trout Lake. This lake will not be designated for the protection of Lake Trout. However, MNDNR fisheries surveys did sample Lake Whitefish and Cisco indicating that this lake supports populations of these coldwater fish species. Considering this information, it is reasonable to retain the Class 2Ag classification for coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]). Trout Lake is not currently designated as a restricted ORVW so the removal of the Lake Trout designation for Trout Lake does not affect the ORVW designation.

Wabana Lake (31-0392-00): Wabana Lake is currently designated Class 2A to protect stream trout. However, this lake is not currently managed or designated as a stream trout lake (Minn. R. 6264.0050) by the MNDNR. However, nine MNDNR fisheries surveys did sample Cisco indicating a population

of this species is supported in this lake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Wasson Lake (31-0281-00): Wasson Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Lake Trout were stocked from 1923-1944, but this species has never been sampled in the four MNDNR fisheries surveys conducted on Wasson Lake. This lake will not be designated for the protection of Lake Trout. However, MNDNR fisheries surveys did sample Cisco in two surveys indicating that this lake supports a population of this coldwater fish species. Considering this information, it is reasonable to designate Wasson Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Class 2Bd designations

The following lake will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting this draft use designation is provided in Table 39 and additional details are provided following the table. For this lake, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering the information below, it is reasonable to assign Class 2Bdg to this lake for the protection of cool and warm waters also protected as a source of drinking water. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River – Grand Rapids watershed (07010103) to acknowledge the cool and warm water status of this lake.

Table 39: List of draft Class 2Bd use designations for lakes in the Mississippi River – Grand Rapids watershed (07010103) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Kennedy	31-0137-00	1.04					$2A^{SRT}$	2Bdg	No	2Bd

Kennedy Lake (31-0137-00): Kennedy Lake is currently designated Class 2A to protect stream trout. It is not currently designated (Minn. R. 6264.0050) or managed as a stream trout lake by the MNDNR. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes the presence of Rainbow Smelt and "good" dissolved oxygen conditions. It was presumably listed as a Class 2A based on the 1967 report. However, there is no indication that this lake supported Lake Trout or any other coldwater fish species at any time. Eight MNDNR fisheries surveys from 1959 through 2003 have not sampled any coldwater fish species (Lake Trout, Lake Whitefish, Cisco, or stream trout). Considering this information, it is reasonable to assign Class 2Bdg to Kennedy Lake for the protection of cool and warm waters also protected as a source of drinking water. This lake is not currently designated as a Lake Trout lake, so the draft designation does not result in the removal of a Lake Trout lake designation.

d. Mississippi River - Brainerd watershed (07010104)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 40 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River - Brainerd watershed (07010104).

Table 40. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River - Brainerd watershed (07010104) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Bass	77-0024-00	1.12			P-6|3|370		2B	2Ag[TLC]	No	2A
Bay	18-0034-00	2.44			P-8|0|187		2B	2Ag[TLC]	No	2A
Big Swan	77-0023-00	3.16			U-5|4|38		2B	2Ag[TLC]	No	2A
Black Bear	18-0140-00	2.08			P-4|0|373		2B	2Ag[TLC]	No	2A
Blue	01-0181-00	0.20	E-0|7|0			RBT-C|N|U	$2A^{SRT}$	2Ag[SRT]	No	SC
Cedar	01-0209-01, -03	0.48-1.77			U-11|2|497		2B	2Ag[TLC]	No	2A
Clearwater	18-0038-00	2.70			P-8|0|262		2B	2Ag[TLC]	No	2A
Crooked	18-0041-01, -02	1.58-2.32			P-11|0|747		2B	2Ag[TLC]	No	2A
Dam	01-0096-00	0.82			P-11|2|185		2B	2Ag[TLC]	No	2A
Farm Island	01-0159-00	0.95			P-10|1|118		2B	2Ag[TLC]	No	2A
Hanks	18-0044-00	2.07			P-10|0|804		2B	2Ag[TLC]	No	2A
Huntington Mine (Martin, Feigh)	18-0441-00	0.32				BNT, RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Lady	77-0032-00	1.55			P-1|7|2		2B	2Ag[TLC]	No	2A
Little Pine	01-0176-00	0.70			P-6|0|48		2B	2Ag[TLC]	No	2A
Little Rabbit	18-0139-00	2.88			P-4|0|111		2B	2Ag[TLC]	No	2A
Little Swan	77-0034-00	1.41			P-7|1|174		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Long	01-0089-00	0.31			P-11|0|251	SPT-C|N|U	2B	2Ag[TLC,SRT]	No	2A
Long	77-0027-00	1.85			U-5|3|83		2B	2Ag[TLC]	No	2A
Mahnomen, Alstead, and Arco Mines	18-0440-01, -02,-03,-04, -05,-06,-07	0.15-0.53	U-0|2|0			RBT-C|Y|M	$2A^{SR}$	2Ag[SRT]	Yes	2A
Mallen Pit	18-0740-00	0.42				BKT, RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Manuel Mine (South Yawkey)	18-0435-00	0.40				RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Miller	18-0133-00	2.38			U-2|0|71		2B	2Ag[TLC]	No	2A
Mons	77-0022-00	1.01			P-4|4|533		2B	2Ag[TLC]	No	2A
Nokay	18-0104-00	3.20			P-8|0|157		2B	2Ag[TLC]	No	2A
Pennington Mine	18-0439-00	0.27	U-0|2|0			RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Portage	18-0050-00	2.89			P-9|1|212		2B	2Ag[TLC]	No	2A
Portsmouth Mine	18-0437-00	0.25				RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Sagamore Mine	18-0523-00	0.41	U-0|3|0			RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Snoshoe Mine	18-0524-00	0.49				RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
South Long	18-0136-00	3.33			P-9|0|163		2B	2Ag[TLC]	No	2A
Spirit	01-0178-00	0.78			P-10|2|87		2B	2Ag[TLC]	No	2A
Unnamed (Section 6)	18-0667-00	0.31				BNT, RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Upper Mission	18-0242-00	3.93			P-7|1|359		2B	2Ag[TLC]	No	2A
Upper South Long	18-0096-00	2.95			P-9|0|152		2B	2Ag[TLC]	No	2A
Yawkey Mine (North Yawkey)	18-0434-00	0.32	U-0|0|0			RBT-C|Y|M	$2A^{SRT}$	2Ag[SRT]	Yes	SC

Big Swan Lake (77-0023-00): Big Swan Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. MNDNR fisheries surveys sampled Cisco in 5 surveys from 1981 through 2000 indicating that this lake supports a population of this coldwater fish species. However, 5 subsequent surveys from 2004 through 2020 have not sampled this species indicating a possible extirpation. Additional targeted sampling is needed to confirm if Cisco have been extirpated from this lake. Although water data indicate limited change in TP and chl-*a* or improving conditions in Secchi depth over time, T_{DO3} may have increased and is now over the 21.2 °C threshold (22.4 °C). Although TP and chl-*a* indicate non-

attainment of goals, these conditions appear to be historically high, and Cisco were present in Big Swan Lake during a period when these water quality parameters were elevated compared to most other Cisco lakes. The greater enrichment may have made this lake more vulnerable to temperature increases and resulted in the extirpation of the Cisco. Big Swan Lake is currently listed as impaired for nutrients. Older MNDNR fisheries survey data demonstrate that a population of Cisco was likely present on or after November 28, 1975, indicating that this lake should be protected for coldwater fish species. Considering this information, it is reasonable to designate Big Swan Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Additional study may be warranted to determine if the Cisco population is extant and if a SSS is appropriate for Big Swan Lake.

Blue Lake (01-0181-00): Blue Lake is currently designated Class 2A to protect stream trout. This lake is currently managed for Rainbow Trout, and it is designated by the MNDNR as a stream trout lake (Minn. R. 6264.0050). It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes "good" dissolved oxygen conditions. Lake Trout are not native and were historically stocked in Blue Lake, but this species has not been present in any of the seven MNDNR fisheries surveys conducted on this lake. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]). Blue lake is also listed as a restricted ORVW presumably due to its listing as a Lake Trout lake in the 1967 report. However, evidence demonstrates that this lake is not a Lake Trout lake and as a result, the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) for Blue Lake will be removed.

Cedar Lake (01-0209-01,-03): Cedar Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco have been routinely sampled (11 of 13 surveys) in the main basin (01-0209-01) and West Bay (01-0209-03). Considering this information, it is reasonable to designate Cedar Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Cedar Lake (N.E. Arm) (01-0209-02) is shallow ($Z_{max} \approx 8$ m) with a small surface area (10 ha) and is unlikely to support coldwater fishes during the period of maximum oxythermal stress. This basin has been surveyed for fish and no Cisco have been collected in the N.E. Arm. As a result, 01-0209-02 will not be included in the coldwater habitat designation.

Dam Lake (01-0096-00): Dam Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in eleven of thirteen MNDNR fisheries surveys indicating that a population of Cisco is present. Dam Lake is connected to Long Lake (01-0089-00) so the Cisco population in Dam Lake may be supplemented from Long Lake. Considering this information, it is reasonable to designate Dam Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Farm Island Lake (01-0159-00): Farm Island Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in ten of eleven MNDNR fisheries surveys indicating that a population of Cisco is present. Considering this information, it is reasonable to designate Farm Island Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Lady (77-0032-00): Lady Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A single MNDNR fisheries survey using gill nets sampled 2 Cisco in 2016, but 7 other surveys did not detect Cisco. A fisheries survey using vertical gill nets was conducted in 2021 and 7 Cisco were sampled. The number of Cisco was not large, but lengths of individuals ranged from 96 to 444 mm indicating natural

recruitment. This indicates that Lady Lake supports a population of Cisco. Considering this information, it is reasonable to designate Lady Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Long Lake (01-0089-00): Long Lake is currently designated Class 2B, but it has been stocked with splake since 2018. It is not a designated MNDNR trout lake (Minn. R. 6264.0050), but it is reasonable to assign the Class 2A classification for coldwater aquatic life and habitat. In addition, eleven MNDNR fisheries surveys sampled Cisco indicating that this lake supports a population of Cisco. Considering this information, it is reasonable to designate Long Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco and stream trout (Class 2Ag [TLC,SRT]).

Mahnomen, Alstead, and Arco Mines (18-0440-01,-02,-03,-04,-05,-06,-07): Mahnomen, Alstead, and Arco Mines (Mahnomen Mine #1-3 [-01,-02,-03], Louise Mine [-04], unnamed mine [-05], Alstead Mine [-06], and Arco Mine [-07]) are currently designated Class 2A. They are managed for Rainbow Trout and are included on the MNDNR designated trout lake list (Minn. R. 6264.0050). These waterbodies have been stocked with Lake Trout and Cisco since 2019, but there is not sufficient information to determine if a fishery for these species can be established. These waterbodies will not be designated for the protection of Lake Trout or Cisco until additional data can be collected to confirm the presence of resident populations of Lake Trout and Cisco. Considering this information, it is reasonable to designate Mahnomen, Alstead, and Arco Mines Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Pennington Mine Lake (18-0439-00): Pennington Mine Lake is currently designated Class 2A to protect stream trout. It is managed for Rainbow Trout and is a MNDNR designated trout lake (Minn. R. 6264.0050). This waterbody has also been stocked with Lake Trout since 2019, but there is not sufficient information to determine if a fishery for this species can be established. This lake will not be designated for the protection of Lake Trout until additional data can be collected to confirm the presence of a resident population of Lake Trout. Considering this information, it is reasonable to designate Pennington Mine Lake Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Sagamore Mine Lake (18-0523-00): Sagamore Mine Lake is currently designated Class 2A to protect stream trout. It is managed for Rainbow Trout and is a MNDNR designated trout lake (Minn. R. 6264.0050). This waterbody has also been stocked with Lake Trout since 2019, but there is not sufficient information to determine if a fishery for this species can be established. This waterbody will not be designated for the protection of Lake Trout until additional data can be collected to confirm the presence of a resident population of Lake Trout. Considering this information, it is reasonable to designate Sagamore Mine Lake Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Yawkey Mine Lake (18-0434-00): Yawkey Mine Lake is currently designated Class 2A to protect stream trout. It is managed for Rainbow Trout and is a MNDNR designated trout lake (Minn. R. 6264.0050). This waterbody was stocked with Lake Trout in 1988, but there have not been any standard gill net surveys conducted on this lake. A gill net survey in 1999, a winter creel survey in 2016, a short-term gill net survey by research staff in 2015, and angler reports indicate that Yawkey Mine Lake supports a population of naturally reproducing Lake Trout. However, there is uncertainty regarding the long-term management goals for this introduced species, and until that is resolved, a Lake Trout designation is not appropriate. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]) in Yawkey Mine Lake.

e. Pine River watershed (07010105)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 41 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout, Lake Whitefish, or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Pine River watershed (07010105).

Table 41. List of draft Class 2A use confirmations and designations for lakes in the Pine River watershed (07010105) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Ada	11-0250-00	2.42			P-12|0|316		2B	2Ag[TLC]	No	2A
Allen	18-0208-00	1.46			E-1|1|57	BKT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Bass	18-0358-00	1.84			U-2|1|28		2B	2Ag[TLC]	No	2A
Bertha	18-0355-00	1.75		P-6|0|94	P-5|1|732		2B	2Ag[LKW,TLC]	No	2A
Big Trout	18-0315-00	1.24	P-7|2|155	P-9|0|343	P-9|0|1846		$2A^{LAT}$	2Ag[LAT,LKW,TLC]	No	SM
Bowen	11-0350-00	3.85			P-6|0|41		2B	2Ag[TLC]	No	2A
Clamshell	18-0356-00	2.26		P-4|2|17	P-6|0|89		2B	2Ag[LKW,TLC]	No	2A
Clear	18-0364-00	1.51			P-6|1|195		2B	2Ag[TLC]	No	2A
Cross Lake Reservoir	18-0312-01	2.02		P-8|0|32	P-8|0|147		2B	2Ag[LKW,TLC]	No	2A
Daggett	18-0271-00	4.55		U-1|6|6	P-7|0|37		2B	2Ag[TLC]	No	2A
Deep Portage	11-0237-00	0.84			P-4|1|96		2B	2Ag[TLC]	No	2A
Eagle	18-0296-01, -02	2.79-2.93			P-6|1|36		2B	2Ag[TLC]	No	2A
East Fox	18-0298-00	1.56			P-5|3|22		2B	2Ag[TLC]	No	2A
Five Point	11-0351-00	2.81		M-1|9|1	P-8|2|70		2B	2Ag[TLC]	No	2A
Hand	11-0242-00	1.87			P-9|0|238		2B	2Ag[TLC]	No	2A
Hattie	11-0232-00	8.02			U-4|0|80		2B	2Ag[TLC]	No	2A
Hay	11-0199-00	2.04			P-9|0|50		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Island	18-0269-00	1.27		P-5|1|38	P-6|0|244		2B	2Ag[LKW,TLC]	No	2A
Kimball	18-0361-00	1.25		U-1|7|1	P-8|0|407		2B	2Ag[TLC]	No	2A
Lawrence	11-0053-00	1.42			U-4|2|14		2B	2Ag[TLC]	No	2A
Leavitt	11-0037-00	1.44			P-8|0|49		2B	2Ag[TLC]	No	2A
Little Andrus (Snowshoe)	11-0054-00	2.35				BKT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Little Pine	18-0266-00	3.15		U-3|3|8	P-6|0|179		2B	2Ag[TLC]	No	2A
Lower Hay	18-0378-00	1.35	U-1|6|1	P-6|1|109	P-6|1|141		$2A^{LAT}$	2Ag[LKW,TLC]	No	SM
Margaret	11-0045-00	1.10				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Marion	11-0046-00	0.85				BKT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Mitchell	18-0294-00	1.52			P-7|0|129		2B	2Ag[TLC]	No	2A
Ossawinnamakee	18-0352-00	2.13		U-1|7|1	P-8|0|484		2B	2Ag[TLC]	No	2A
Pelican	18-0308-00	2.41		U-1|17|3	P-17|1|284		2B	2Ag[TLC]	No	2A
Pig	18-0354-00	1.74		P-6|0|29	P-6|0|224		2B	2Ag[LKW,TLC]	No	2A
Pine Mountain	11-0411-00	2.11			P-13|1|144		2B	2Ag[TLC]	No	2A
Pleasant	18-0278-00	0.81				BKT, RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Roosevelt	11-0043-01, -02	1.20 -1.44	E-4|6|42		P-10|0|2543		$2A^{LAT}$	2Ag[TLC]	Yes	SM
Rush	18-0311-00	1.35		P-7|0|137	P-7|0|645		2B	2Ag[LKW,TLC]	No	2A
Star	18-0359-00	1.05			P-3|0|62		2B	2Ag[TLC]	No	2A
Strawberry (Lost)	18-0363-00	1.32				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Washburn	11-0059-00	1.49			P-10|0|315		2B	2Ag[TLC]	No	2A
West Fox	18-0297-00	2.19			P-7|2|101		2B	2Ag[TLC]	No	2A
Whitefish	18-0310-00	1.78		P-12|0|215	P-12|0|782		2B	2Ag[LKW,TLC]	No	2A

Allen Lake (18-0208-00): Allen Lake is currently designated Class 2A to protect stream trout. This lake is currently managed for Brook Trout and Rainbow Trout and is designated by the MNDNR as a stream trout lake (Minn. R. 6264.0050). Cisco were stocked in this lake in 1977, and a high number of Cisco were collected in 1989. However, this lake was reclaimed in 2007 which resulted in the removal of the Cisco population. This lake is also atypically small (18 ha) for a Cisco lake indicating that Allen Lake may not have supported a Cisco population in the long term. This lake will not be designated for the protection of Cisco at this time because these fish were not native, it is not clear how suitable this lake is to support a population of Cisco, and the

applicable water quality criteria for stream trout are more protective. Even if the stream trout designation was removed from this lake, the northern warm-water lake eutrophication standards are more protective than the Cisco eutrophication standard and therefore would result in the maintenance of water quality conditions. Considering this information, it is reasonable to retain the Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

Big Trout Lake (18-0315-00): Big Trout Lake is currently designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes "good" dissolved oxygen conditions. It is not known if Lake Trout are native to this lake, but stocking of Lake Trout began in 1930. During the period of stocking, carryover has occurred, but natural recruitment has not. The Lake Trout fishery has been determined to not be sustainable, but stocking of Lake Trout is ongoing to maintain a population. It is reasonable to assign protections for Lake Trout to this lake, but because the presence of Lake Trout is contingent on stocking, the cessation of stocking could result in a change to the use designation for this lake. Big Trout Lake supports natural populations of Lake Whitefish and Cisco. In nine MNDNR surveys (1950-2011), Cisco and Lake Whitefish were sampled in all 9 surveys (Cisco: n=1,364; Lake Whitefish: n=272). Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Lake Trout, Lake Whitefish, and Cisco (Class 2Ag [LAT,LKW,TLC]).

Cross Lake Reservoir (18-0312-01): Cross Lake Reservoir is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cross Lake Reservoir is delineated into three basins in the MPCA's waterbody database. Only the main basin (18-0312-01) appears to be deep enough to support coldwater fish species. The other basins (Southeast Bay [18-0312-02] and Unnamed Bay [18-0312-03]) are shallow (Z_{max} = <3 m) and are unlikely to support coldwater fishes during the period of maximum oxythermal stress. The MNDNR has consistently sampled Lake Whitefish and Cisco in this lake indicating that these species are supported in this lake. Considering this information, it is reasonable to designate the main basin of Cross Lake Reservoir a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Whitefish and Cisco (Class 2Ag [LKW,TLC]).

Daggett Lake (18-0271-00): Daggett Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Seven MNDNR fisheries surveys have been conducted on this lake and Cisco were present in every survey. Lake Whitefish were sampled in one of these surveys with a total of 6 fish sampled. These Lake Whitefish may have been transient as Daggett Lake is connected to Cross Lake Reservoir (18-0312). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected which demonstrates that a resident population of Lake Whitefish is present. As a result, it is reasonable to designate Daggett Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco only (Class 2Ag [TLC]).

Eagle Lake (18-0296-01,-02): Eagle Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco have been routinely sampled (6 of 7 surveys) in the Main Bay (18-0296-01) and West Bay (18-0296-02). Considering this information, it is reasonable to designate Eagle Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Eagle Lake (East Bay) (18-0296-03) is shallow (Z_{max} = 6 m) with a small surface area (27 ha) and is unlikely to support coldwater fishes during the period of maximum oxythermal stress. This basin has been surveyed for fish and no Cisco have been collected in the East Bay. As a result, 18-0296-03 will not be included in the coldwater habitat designation.

Five Point Lake (11-0351-00): Five Point Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Ten MNDNR fisheries surveys have been conducted and Cisco were present in eight of these surveys. In the 1977 fisheries survey, a single Lake Whitefish was identified. This is the only survey from Five Point Lake which included fish identified as Lake Whitefish, indicating that these fish may represent a misidentification. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Five Point Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Kimball Lake (18-0361-00): Kimball Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eight MNDNR fisheries surveys have been conducted and Cisco were present in all surveys. In the 1999 fisheries survey, a single Lake Whitefish was identified. Several lakes in the Pelican Brook (070101050603) and Pelican Lake (070101050602) subwatersheds (i.e., 12-digit HUC) had small and irregular catches of Lake Whitefish indicating that these fish may be transient. These lakes are connected to the Pine River and Whitefish Chain of Lakes which may be the source of these fish. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected which demonstrates that a resident population of Lake Whitefish is present. As a result, it is reasonable to designate Kimball Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Little Pine Lake (18-0266-00): Little Pine Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Six MNDNR fisheries surveys have been conducted on this lake and Cisco were present in every survey. Lake Whitefish were sampled in three of these surveys with a total of 8 fish sampled. These Lake Whitefish present may have been transient as Little Pine Lake is connected to Cross Lake Reservoir (18-0312). This lake will not be designated for the protection of Lake Whitefish until additional data can be collected to confirm the presence of a resident population of Lake Whitefish. As a result, it is reasonable to designate Little Pine Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Lower Hay Lake (18-0378-00): Lower Hay Lake is currently designated Class 2A to protect Lake Trout. It is listed as a “potential inland lake trout lake” in Minnesota Department of Conservation (1967) which also notes “good” dissolved oxygen conditions. The Class 2A designation of Lower Hay Lake was initially based on its potential to support Lake Trout. This lake was intermittently stocked with Lake Trout between 1911 and 1945 although there is no evidence that natural recruitment occurred. In 2005, a MNDNR fisheries survey collected a single Lake Trout, but this was determined to likely be a migrant from Big Trout Lake (18-0315-00). Currently there is no evidence that this lake supports a population of Lake Trout given the low numbers of trout collected despite past stocking efforts and connectivity with a lake stocked with Lake Trout. This lake will not be designated for the protection of Lake Trout because it is not managed for Lake Trout and a Lake Trout fishery has been determined to not be sustainable. However, Lower Hay Lake supports natural populations of Lake Whitefish and Cisco. In seven MNDNR surveys (1950-2018), Lake Whitefish and Cisco were sampled in 6 surveys (Cisco: n= 149; Lake Whitefish: n=109). Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat. The designation for Lower Hay Lake will be based on the protection of Cisco and Lake Whitefish and will be designated Class 2Ag [TLC,LKW]). Lower Hay Lake is not designated as a restricted ORVW designation so the removal of the Lake Trout designation for Lower Hay Lake does not affect the ORVW designation.

Ossawinnamakee Lake (18-0352-00): Ossawinnamakee Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eight MNDNR fisheries surveys have been conducted on this lake and Cisco were present in every survey. A single Lake Whitefish was sampled in one of these surveys. Several lakes in the Pelican Brook (070101050603) and Pelican Lake (070101050602) subwatersheds (i.e., 12-digit HUC) had small and irregular catches of Lake Whitefish indicating that these fish may be transient. These lakes are connected to the Pine River and Whitefish Chain of Lakes which may be the source of these fish. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected which demonstrates that a resident population of Lake Whitefish is present. As a result, it is reasonable to designate Ossawinnamakee Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco only (Class 2Ag [TLC]).

Pelican Lake (18-0308-00): Pelican Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Eighteen MNDNR fisheries surveys have been conducted on this lake and Cisco were present in seventeen of these surveys. Lake Whitefish were sampled in one of these surveys with a total of 3 fish sampled. Several lakes in the Pelican Brook (070101050603) and Pelican Lake (070101050602) subwatersheds (i.e., 12-digit HUC) had small and irregular catches of Lake Whitefish indicating that these fish may be transient. These lakes are connected to the Pine River and Whitefish Chain of Lakes which may be the source of these fish. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected which demonstrates that a resident population of Lake Whitefish is present. As a result, it is reasonable to designate Pelican Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Roosevelt Lake (North [11-0043-01] and South [11-0043-02]): Roosevelt Lake is currently designated Class 2A to protect Lake Trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes "good" dissolved oxygen conditions and an "adverse fish population." The MNDNR began stocking Lake Trout in 1982. During the period of stocking, carryover was observed, but natural recruitment was not. The Lake Trout fishery was determined to not be sustainable, and stocking ceased in 2006. Roosevelt Lake supports a natural population of Cisco. In ten MNDNR fisheries surveys (1968-2018), Cisco were collected in all surveys and a total of 2,543 individuals were sampled. Considering this information, it is reasonable to retain the Class 2Ag classification assigned to coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). As a result, the removal of the Lake Trout lake designation will also remove the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) from Roosevelt Lake.

Class 2Bd designations

The following lake will be designated for the protection of warm and cool water aquatic life and habitat (Class 2Bd). A summary of the evidence supporting the draft use designation is provided in Table 42 and additional details are provided following the table. For these lakes, the designation of Class 2Bd from Class 2A results in the designation of a beneficial use that carries with it less stringent standards. As a result, a use attainability analysis (40 CFR § 131.3(g)) is required by the CWA (40 CFR § 131.10(j)) to demonstrate that the current use designation is not an existing use (40 CFR § 131.3(e)) or an attainable use (40 CFR § 131.10(d)). Considering the information below, it is reasonable to assign Class 2Bdg to this lake for the protection of cool and warm waters also protected as a source of drinking water. The MPCA use designation for this lake will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Pine River Watershed (07010105).

Table 42: List of draft Class 2Bd use designations for lakes in the Pine River watershed (07010105) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Willard	11-0564-00	1.15				NA-H|N|U	2A^{SRT}	2Bdg	No	2Bd

Willard Lake (11-0564-00): Willard Lake is currently designated Class 2A to protect stream trout. Willard Lake is proposed to be designated as a cool and warm water aquatic life and habitat also protected as a source of drinking water (Class 2Bd). Stocking of Rainbow Trout was discontinued in 2009 and the MNDNR no longer manages or lists Willard Lake as a trout lake (Minn. R. 6264.0050). Management and delisting of this lake occurred due to a poor forage base for trout (zooplankton) and the introduction of other fish species including black crappie (*Pomoxis nigromaculatus* [Lesueur, 1829]) and Yellow Perch, which can negatively impact the stream trout fishery. Fourteen surveys did not sample Lake Trout, Lake Whitefish, or Cisco. Considering this information, it is reasonable to assign Class 2Bdg to Willard Lake for the protection of cool and warm waters also protected as a source of drinking water.

f. Crow Wing River watershed (07010106)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 43 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Crow Wing River watershed (07010106).

Table 43. List of draft Class 2A use confirmations and designations for lakes in the Crow Wing River watershed (07010106) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Big Sand	29-0185-00	1.23			P-10|5|350		2B	2Ag[TLC]	No	2A
Blue	29-0184-00	1.32			P-10|2|1051	RBT-C|N|U	2A^{SRT}	2Ae[TLC,SRT]	No	SM
Boot	03-0030-00	1.06			P-1|11|1		2B	2Ae[TLC]	No	2A
Eagle	29-0256-00	1.54			P-10|0|101		2B	2Ae[TLC]	No	2A
East Crooked	29-0101-01	1.19			U-7|4|172		2B	2Ag[TLC]	No	2A
Edna	18-0396-00	1.46			P-5|0|67		2B	2Ag[TLC]	No	2A
Edward	18-0305-00	2.49		E-0|8|0	E-5|3|46		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Eleventh Crow Wing	29-0036-01,-02	1.53-1.84			P-9|1|1229		2B	2Ae[TLC]	No	2A
Emma	29-0186-00	1.50			U-4|4|34		2B	2Ag[TLC]	No	2A
Fifth Crow Wing	29-0092-00	3.34			P-8|3|135		2B	2Ae[TLC]	No	2A
Fish Hook	29-0242-00	2.19			P-9|2|121		2B	2Ae[TLC]	No	2A
Gull	11-0305-00	3.26			P-17|0|1066		2B	2Ae[TLC]	No	2A
Hubert	18-0375-00	2.21			U-6|2|53		2B	2Ag[TLC]	No	2A
Island	29-0254-00	1.93			P-10|0|198		2B	2Ae[TLC]	No	2A
Little Sand	29-0150-00	1.47			P-5|5|9		2B	2Ag[TLC]	No	2A
Long	29-0161-00	1.35			P-8|3|288		2B	2Ae[TLC]	No	2A
Lower Bottle	29-0180-00	1.02			U-5|6|18		2B	2Ag[TLC]	No	2A
Lower Cullen	18-0403-00	3.27			P-8|0|628		2B	2Ag[TLC]	No	2A
Mantrap	29-0151-01,-02, -03,-04,-05	1.45-3.91			P-9|1|171		2B	2Ag[TLC]	No	2A
Margaret	11-0222-00	3.97			P-4|4|43		2B	2Ag[TLC]	No	2A
Middle Cullen	18-0377-00	2.53			P-8|0|784		2B	2Ae[TLC]	No	2A
Ninth Crow Wing	29-0025-00	1.57			P-7|2|142		2B	2Ae[TLC]	No	2A
North Long	18-0372-00	2.39			P-10|0|469		2B	2Ag[TLC]	No	2A
Perch	11-0826-00	1.28				RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Pillager	11-0320-00	2.52			P-6|0|988		2B	2Ag[TLC]	No	2A
Potato	29-0243-00	2.03			P-12|1|635		2B	2Ae[TLC]	No	2A
Round	18-0373-00	3.27			P-10|1|352		2B	2Ag[TLC]	No	2A
Second Crow Wing	29-0085-00	2.89			U-9|1|137		2B	2Ag[TLC]	No	2A
Seventh Crow Wing	29-0091-00	2.61			P-11|0|164		2B	2Ae[TLC]	No	2A
Sixth Crow Wing	29-0093-00	2.80			P-9|2|176		2B	2Ae[TLC]	No	2A
Spider	29-0117-01,-02	1.27-1.29			P-4|7|8		2B	2Ag[TLC]	No	2A
Straight	03-0010-00	1.94			P-9|1|86		2B	2Ag[TLC]	No	2A
Tenth Crow Wing	29-0045-00	2.38			P-8|1|85		2B	2Ae[TLC]	No	2A
Third Crow Wing	29-0077-00	3.99			P-11|0|316		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Tripp	29-0005-00	1.41			U-3|0|265		2B	2Ag[TLC]	No	2A
Two Inlets	03-0017-00	2.13			P-12|0|165		2B	2Ae[TLC]	No	2A
Upper Bottle	29-0148-00	2.02			U-5|6|10		2B	2Ag[TLC]	No	2A
Upper Cullen	18-0376-00	2.96			P-6|2|147		2B	2Ae[TLC]	No	2A
Upper Gull	11-0218-00	2.19			P-9|0|503		2B	2Ag[TLC]	No	2A

Blue Lake (29-0184-00): Blue Lake is currently designated Class 2A to protect stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967). Stocking records show that during the period 1910 to 1945 Walleye, Northern Pike, Lake Trout, and bass were stocked. However, there have been 12 MNDNR fisheries surveys conducted on this lake since 1957 and none of these sampled Lake Trout. Rainbow Trout stocking began in 1984, and although it is not a MNDNR designated stream trout lake (Minn. R. 6264.0050), the lake is currently managed for stream trout. Cisco were sampled in ten of the MNDNR fisheries surveys indicating that Blue Lake supports a population of this coldwater fish species. Considering this information, it is reasonable to retain the Class 2A designation for the protection of coldwater aquatic life and habitat and assign protections for Cisco and stream trout (Class 2Ae [TLC,SRT]). Blue Lake is also listed as a restricted ORVW. This designation was presumably due to its listing as a potential Lake Trout lake in the 1967 report. However, evidence demonstrates that this lake is not a Lake Trout lake and as a result, the restricted ORVW designation (Minn. R. 7050.0335, subp. 1, Item C) for Blue Lake will be removed. Documentation for the Exceptional Use designation is provided in MPCA (2024c).

Boot Lake (03-0030-00): Boot Lake is currently designated Class 2B and is not designated for the protection of any coldwater fish species. A single Cisco was present in one of MNDNR's 12 fisheries surveys. However, a high number of Cisco (n=43) were sampled in a 2020 MNDNR vertical gill net survey indicating that Boot Lake supports a population of Cisco. Considering this information, it is reasonable to designate Boot Lake a Class 2Ae for the protection of Exceptional coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ae [TLC]). Documentation for the Exceptional Use designation is provided in MPCA (2024c).

Edward Lake (18-0305-00): Edward Lake is currently designated Class 2B and is not designated for the protection of any coldwater fish species. Five MNDNR fisheries surveys have sampled Cisco indicating that Edward Lake supports a population of Cisco. "Whitefish" fry were stocked once in the 1920s, but Lake Whitefish have never been sampled by MNDNR fisheries surveys. Considering this information, it is reasonable to designate Edward Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Little Sand Lake (29-0150-00): Little Sand Lake is currently designated Class 2B and is not designated for the protection of any coldwater fish species. Nine Cisco were sampled in five MNDNR fisheries surveys. In addition, a moderate number of Cisco (n=23) were sampled in a 2019 MNDNR vertical gill net survey. This information indicates that Little Sand Lake supports a population of Cisco. Considering this information, it is reasonable to designate Little Sand Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

g. Redeye River watershed (07010107)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 44. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Redeye River watershed (07010107).

Table 44. List of draft Class 2A use confirmations and designations for lakes in the Redeye River watershed (07010107) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
East Leaf	56-0116-02	2.51			U-6|3|60		2B	2Ag[TLC]	No	2A
Middle Leaf	56-0116-01	2.72			P-7|1|31		2B	2Ag[TLC]	No	2A
West Leaf	56-0114-00	2.64			P-8|1|81		2B	2Ag[TLC]	No	2A

h. Long Prairie River watershed (07010108)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 45 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Long Prairie River watershed (07010108).

Table 45. List of draft Class 2A use confirmations and designations for lakes in the Long Prairie River watershed (07010108) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Alexander	49-0079-00	2.89			P-7|6|87		2B	2Ae[TLC]	No	2A
Andrew	21-0085-00	1.75			P-11|0|145		2B	2Ag[TLC]	No	2A
Brophy	21-0102-00	2.45			U-6|3|29		2B	2Ag[TLC]	No	2A
Burgen	21-0049-00	2.20			P-9|1|254		2B	2Ag[TLC]	No	2A
Carlos	21-0057-00	1.15			P-2|12|11		2B	2Ag[TLC]	No	2A

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Charlotte	77-0120-00	1.09		M-1|8|31	P-6|3|326		2B	2Ae[TLC]	No	2A
Cowdrey	21-0103-00	1.98			P-7|2|55		2B	2Ag[TLC]	No	2A
Darling	21-0080-00	2.40			P-8|1|152		2B	2Ag[TLC]	No	2A
Fish Trap	49-0137-00	3.63			P-7|5|20		2B	2Ag[TLC]	No	2A
Geneva	21-0052-00	2.10			U-6|4|51		2B	2Ag[TLC]	No	2A
Ida	21-0123-00	2.01			P-16|1|88		2B	2Ae[TLC]	No	2A
Irene	21-0076-00	2.99			P-8|0|127		2B	2Ag[TLC]	No	2A
Latoka	21-0106-01,-02	1.15-1.22			P-10|0|158		2B	2Ag[TLC]	No	2A
Le Homme Dieu	21-0056-00	2.00			P-8|3|56		2B	2Ag[TLC]	No	2A
Lobster	21-0144-01,-02	2.07-3.81			U-6|4|152		2B	2Ag[TLC]	No	2A
Lottie	21-0105-00	2.24			U-3|4|16		2B	2Ag[TLC]	No	2A
Louise	21-0094-00	3.01			U-7|1|69		2B	2Ag[TLC]	No	2A
Mill	21-0180-00	2.99			U-8|3|157		2B	2Ag[TLC]	No	2A
Miltona	21-0083-00	2.16			P14|2|199		2B	2Ae[TLC]	No	2A
Mina	21-0108-00	0.96			P-8|1|119		2B	2Ae[TLC]	No	2A
North Union	21-0095-00	2.05			P-4|3|18		2B	2Ag[TLC]	No	2A
Stony	21-0101-00	1.38			U-4|3|23		2B	2Ag[TLC]	No	2A
Turtle	77-0088-00	2.17			P-7|1|165		2B	2Ag[TLC]	No	2A
Victoria	21-0054-00	1.97			P-7|3|105		2B	2Ag[TLC]	No	2A

Charlotte Lake (77-0120-00): Charlotte Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Six MNDNR fisheries surveys on this lake sampled Cisco. A fisheries survey in 1978 collected 31 fish identified as Lake Whitefish, but no fish were identified as Cisco. These data indicate a possible misidentification since Cisco were present in most other surveys. This lake will not be designated for the protection of Lake Whitefish until additional data can be collected that demonstrates the presence of a resident population of Lake Whitefish in this lake. As a result, it is reasonable to designate Charlotte Lake a Class 2Ae for the protection of coldwater aquatic life and habitat and assign protections for Cisco only (Class 2Ae [TLC]). Documentation for the Exceptional Use designation is provided in MPCA (2024c).

Fish Trap Lake (49-0137-00): Fish Trap Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Seven of twelve MNDNR fisheries surveys on this lake sampled low numbers of Cisco. Fish Trap Lake is connected to Alexander Lake (49-0079-00) so the Cisco population in Fish Trap Lake may be supplemented from Alexander Lake. However, smaller fish have been sampled in Fish Trap Lake indicating that

natural reproduction is occurring in this lake. Considering this information, it is reasonable to designate Fish Trap Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

i. Mississippi River - Sartell watershed (07010201)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 46 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River - Sartell watershed (07010201).

Table 46. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River - Sartell watershed (07010201) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Big Watab	73-0102-00	0.84				BNT, RBT-C|N|U	$2A^{SRT}$	2Ag[SRT]	No	SC
Cedar	49-0140-00	1.17			U-4|3|103		2B	2Ag[TLC]	No	2A
Middle Spunk	73-0128-00	1.26			P-6|0|368		2B	2Ag[TLC]	No	2A
Sullivan	49-0016-00	2.64			U-8|3|52		2B	2Ag[TLC]	No	2A

Big Watab Lake (73-0102-00): Big Watab Lake is currently designated Class 2A to protect stream trout. It is listed as a "potential inland lake trout lake" in Minnesota Department of Conservation (1967) which notes that this lake has "good" dissolved oxygen conditions. Six MNDNR fisheries surveys have been conducted on this lake and Lake Trout have not been sampled nor there is evidence this lake ever supported a Lake Trout population. Rainbow Trout stocking began in 1989, and although not a MNDNR designated stream trout lake (Minn. R. 6264.0050), the lake is currently managed for stream trout. Considering this information, it is reasonable to retain the Class 2Ag designation for the protection of coldwater aquatic life and habitat and assign protections for stream trout (Class 2Ag [SRT]).

j. Sauk River watershed (07010202)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 47 and if needed, additional information is provided following this table. Available evidence demonstrates that

these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Sauk River watershed (07010202).

Table 47. List of draft Class 2A use confirmations and designations for lakes in the Sauk River watershed (07010202) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Big Birch	77-0084-01,-02	1.71-1.97			P-10|0|140		2B	2Ag[TLC]	No	2A
Fairy	77-0154-00	3.08			P-5|4|16		2B	2Ag[TLC]	No	2A
Little Birch	77-0089-00	1.58			P-8|2|144		2B	2Ag[TLC]	No	2A
Osakis	77-0215-00	3.49			P-14|1|285		2B	2Ag[TLC]	No	2A
Sauk	77-0150-02	2.75			P-11|0|415		2B	2Ag[TLC]	No	2A
St. Anna	73-0183-00	0.82			E-1|5|8		2B	2Ag[TLC]	No	2A
Sylvia	73-0249-00	1.42			U-6|1|147		2B	2Ag[TLC]	No	2A

Big Birch Lake (77-0084-01, -02): Big Birch Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in all ten MNDNR fisheries surveys (1981-2018) indicating that this lake supports a population of Cisco. As a result, it is reasonable to designate Big Birch a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Sauk Lake (77-0150-02): Sauk Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in all eleven MNDNR fisheries surveys (1972-2019) indicating that this lake supports a population of Cisco. As a result, it is reasonable to designate Sauk a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Sauk Lake (Southwest Bay) (77-0150-01) is shallow (Z_{max} = <6 m) and is unlikely to support coldwater fishes during the period of maximum oxythermal stress. As a result, 77-0150-01 will not be included in the coldwater habitat designation.

St. Anna Lake (73-0183-00): St. Anna Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A low number of Cisco (n=8) were sampled in a MNDNR fisheries survey in 1980, and this species was present in a MNDNR gill net survey (n=2) in 1973. Cisco have not been sampled in 5 subsequent surveys which may indicate Cisco have been extirpated from St. Anna Lake. However, the presence of this species in 1980 indicates that a Cisco coldwater habitat is an existing use. As a result, it is reasonable to designate St. Anna Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]). Due to the limited monitoring (i.e., a two fisheries surveys) and the small catch size, it is possible that additional information could result in a change to this designation.

k. Mississippi River - St. Cloud watershed (07010203)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provide Table 48 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Mississippi River - St. Cloud watershed (07010203).

Table 48. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River - St. Cloud watershed (07010203) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Augusta	86-0284-00	1.14			P-6|1|87		2B	2Ag[TLC]	No	2A
Cedar	86-0227-00	1.28			E-4|3|54		2B	2Ag[TLC]	No	2A
Clearwater	86-0252-01,-02	2.28-3.19			U-4|3|12		2B	2Ag[TLC]	No	2A
Little Mud	47-0096-00	1.54				RBT-C|N|U	2B	2Ag[SRT]	No	2A
Otter	73-0015-00	1.61			U-3|1|6		2B	2Ag[TLC]	No	2A
Pleasant	86-0251-00	1.74			E-2|9|11		2B	2Ag[TLC]	No	2A
Sugar	86-0233-00	2.13			P-5|2|15		2B	2Ag[TLC]	No	2A

Cedar Lake (86-0227-00): Cedar Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in MNDNR fisheries surveys until 1996, but Cisco have not been sampled in 3 subsequent surveys and a MNDNR vertical gill net survey. This indicates that Cisco may have been extirpated from Cedar Lake. However, the presence of this species until at least 1996 indicates that a Cisco coldwater habitat is an existing use. As a result, it is reasonable to designate Cedar Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Otter Lake (73-0015-00): Otter Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Six Cisco were sampled in three MNDNR fisheries surveys and dead Cisco were observed in another survey (2011). This information indicates that Otter Lake supports or supported a population of Cisco. As a result, it is reasonable to designate Otter Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Pleasant Lake (86-0251-00): Pleasant Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in 1980 and 1986 in MNDNR fisheries surveys. Cisco have not been sampled in 4 subsequent surveys which may indicate Cisco have been

extirpated from Pleasant Lake. This lake was historically connected to Clearwater Lake (86-0252-00), but an outlet structure prevents fish passage and may be preventing reestablishment of a Cisco population. However, the presence of this species in 1980 and 1986 indicates that a Cisco coldwater habitat is an existing use. As a result, it is reasonable to designate Pleasant Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

l. North Fork Crow River watershed (07010204)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 49 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the North Fork Crow River watershed (07010204).

Table 49. List of draft Class 2A use confirmations and designations for lakes in the North Fork Crow River watershed (07010204) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
East Lake Sylvia	86-0289-00	1.71			U-2|5|3		2B	2Ag[TLC]	No	2A
Green	34-0079-00	2.05			U-30|7|731		2B	2Ag[TLC]	No	2A
Koronis (main lake)	73-0200-02	1.46			P-16|5|243		2B	2Ag[TLC]	No	2A
West Lake Sylvia	86-0279-00	1.62			U-1|5|1		2B	2Ag[TLC]	No	2A

East Lake Sylvia (86-0289-00): East Lake Sylvia is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Five Cisco were sampled in two MNDNR fisheries surveys and were also present in a James Ford Bell Museum survey in 1984. This information indicates that East Lake Sylvia supports or supported a population of Cisco. As a result, it is reasonable to designate East Lake Sylvia a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Green Lake (34-0079-00): Green Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in 30 of 37 MNDNR fisheries surveys (1956-2020) indicating that this lake supports a population of Cisco. As a result, it is reasonable to designate Green a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

Koronis (main lake) Lake (73-0200-02): Koronis Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco were sampled in 16 of 21 MNDNR fisheries surveys (1950-2019) indicating that this lake supports a population of Cisco. As a result, it is reasonable to designate Koronis a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

West Lake Sylvia (86-0279-00): West Lake Sylvia is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. A single Cisco was sampled in a MNDNR fisheries survey in 1981 and a moderate number (n=23) were sampled in a MNDNR vertical gill net survey in 2015. This information indicates that West Lake Sylvia supports or supported a population of Cisco. As a result, it is reasonable to designate West Lake Sylvia a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

m. South Fork Crow River watershed (07010205)

No draft use designations or confirmations

n. Mississippi River - Twin Cities watershed (07010206)

Class 2A confirmations and designations

The following lake will be confirmed for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting this use designation is provided in Table 50. The use designation for this lake will be amended Minn. R. 7050.0470 by updating the beneficial uses for this lake in the Mississippi River - Twin Cities watershed (07010206).

Table 50. List of draft Class 2A use confirmations and designations for lakes in the Mississippi River - Twin Cities watershed (07010206) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Unnamed (Cenaiko)	02-0654-00	1.67	E-0|4|0			RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC

o. Rum River watershed (07010207)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 51. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Rum River watershed (07010207).

Table 51. List of draft Class 2A use confirmations and designations for lakes in the Rum River watershed (07010207) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Barbour	18-0030-00	1.37			P-2|1|123		2B	2Ag[TLC]	No	2A
Borden	18-0020-00	1.74			U-7|1|111		2B	2Ag[TLC]	No	2A
Kenney	18-0019-00	1.52			U-2|0|53		2B	2Ag[TLC]	No	2A
Round	01-0204-00	0.33			P-8|1|251		2B	2Ag[TLC]	No	2A
Smith	18-0028-00	2.24			P-4|0|84		2B	2Ag[TLC]	No	2A
Whitefish	18-0001-00	2.18			P-4|0|238		2B	2Ag[TLC]	No	2A

5. Minnesota River basin

a. Minnesota River - Headwaters watershed (07020001)

No draft use designations or confirmations

b. Pomme de Terre River watershed (07020002)

Class 2A confirmations and designations

The following lake will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting this use designation is provided in Table 52. Available evidence demonstrates that this lake supports or should support a naturally reproducing populations of Cisco. The use designation for this lake will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Pomme de Terre River watershed (07020002).

Table 52. List of draft Class 2A use confirmations and designations for lakes in the Pomme de Terre River watershed (07020002) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Stalker	56-0437-00	1.67			U-5|6|15		2B	2Ag[TLC]	No	2A

c. Lac qui Parle River watershed (07020003)

No draft use designations or confirmations

d. Minnesota River - Yellow Medicine River watershed (07020004)

No draft use designations or confirmations

e. Chippewa River watershed (07020005)

Class 2A confirmations and designations

The following lakes will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 53. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Cisco. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Chippewa River watershed (07020005).

Table 53. List of draft Class 2A use confirmations and designations for lakes in the Chippewa River watershed (07020005) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Chippewa	21-0145-00	1.59			P-7|3|60		2B	2Ag[TLC]	No	2A
Rachel	21-0160-00	1.84			P-8|1|181		2B	2Ag[TLC]	No	2A

f. Redwood River watershed (07020006)

No draft use designations or confirmations

g. Minnesota River - Mankato watershed (07020007)

No draft use designations or confirmations

h. Cottonwood River watershed (07020008)

No draft use designations or confirmations

i. Blue Earth River watershed (07020009)

No draft use designations or confirmations

j. Watonwan River watershed (07020010)

No draft use designations or confirmations

k. Le Sueur River watershed (07020011)

No draft use designations or confirmations

l. Lower Minnesota River watershed (07020012)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 54 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lower Minnesota River watershed (07020012).

Table 54. List of draft Class 2A use confirmations and designations for lakes in the Lower Minnesota River watershed (07020012) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Courthouse	10-0005-00	0.84	E-1|2|1			BKT,BNT,RBT-C|Y|U	$2A^{SRT}$	2Ag[SRT]	Yes	SC
Quarry	70-0343-00	1.06				BKT,BNT,RBT-C|Y|M	2B	2Ag[SRT]	Yes	2A

Quarry Lake (70-0343-00): Quarry Lake will be proposed to be designated as a coldwater aquatic life and habitat (Class 2A). The MNDNR added Quarry Lake to its list of designated trout lakes (Minn. R. 6264.0050) in 2018 (State of Minnesota 2018). Temperature and dissolved oxygen levels indicate that the lake can support trout and it is currently stocked with Rainbow Trout. Considering this information, it is reasonable to designate Quarry Lake coldwater habitat and assign protections for stream trout (Class 2Ag [SRT]).

6. Saint Croix River basin

a. Upper St. Croix River watershed (07030001)

No draft use designations or confirmations

b. Kettle River watershed (07030003)

Class 2A confirmations and designations

The following lakes will be confirmed or designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting these use designations is provided in Table 55 and if needed, additional information is provided following this table. Available evidence demonstrates that these lakes support or should support naturally reproducing populations of Lake Trout or Cisco or are managed for coldwater fish through stocking. The use designations for these lakes will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Kettle River watershed (07030003).

Table 55. List of draft Class 2A use confirmations and designations for lakes in the Kettle River watershed (07030003) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Grindstone	58-0123-00	0.82	P-8|0|580		E-3|5|11	BNT, RBT-C|N|U	$2A^{LAT}$	2Ag[LAT,TLC,SRT]	No	SM
Hanging Horn	09-0038-00	1.40	E-1|11|2		P-12|0|3452	NA-H|N|U	2B	2Ag[TLC]	No	2A
Little Hanging Horn	09-0035-00	1.22			U-6|1|49		2B	2Ag[TLC]	No	2A

Grindstone Lake (58-0123-00): Grindstone Lake is currently designated Class 2A to protect Lake Trout. It is listed as an "inland lake trout lake" in Minnesota Department of Conservation (1967) which also notes that the lake has "poor reproduction." Lake Trout are managed in this lake and although the population is not self-sustaining, good numbers are present in fisheries surveys. Cisco were sampled in all MNDNR fisheries surveys from 1949-1992, but this species has not been sampled in any gill net sampling efforts since. Cisco may have been extirpated by the introduction Rainbow Smelt. Since the Cisco population was possibly native and occurred after November 28, 1975, this is an existing use, and it should be protected. Although it is not a designated stream trout lake, Grindstone Lake is also managed for Brown and Rainbow Trout. Considering this information, it is reasonable to designate Grindstone Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Lake Trout, Cisco, and stream trout (Class 2Ag [LAT,TLC,SRT]).

Hanging Horn Lake (09-0038-00): Hanging Horn Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Twelve MNDNR fisheries surveys conducted on Hanging Horn Lake all sampled Cisco indicating that this lake supports a population of Cisco.

Lake Trout were stocked in 2007, but this effort failed to produce a Lake Trout fishery and stocking was discontinued. Hanging Horn Lake was historically managed for Rainbow and Brown Trout, but it is no longer managed for stream trout, and it is not a designated stream trout lake. Considering this information, it is reasonable to designate Hanging Horn Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

c. Snake River watershed (07030004)

No draft use designations or confirmations

d. Lower St. Croix River watershed (07030005)

Class 2A confirmations and designations

The following lake will be designated for the protection of coldwater aquatic life and habitat (Class 2A). A summary of the evidence supporting the use designation is provided in Table 56 and additional details are provided following this table. Available evidence demonstrates that this lake supports or should support a naturally reproducing population of Cisco. The use designation for this lake will be amended in Minn. R. 7050.0470 by updating the beneficial uses for lakes in the Lower St. Croix River watershed (07030005).

Table 56. List of draft Class 2A use confirmations and designations for lakes in the Lower St. Croix River watershed (07030005) with supporting information. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

Lake name	WID	GR	Fisheries survey: LAT	Fisheries survey: LKW	Fisheries survey: TLC	Fisheries survey: SRT	Current ALU	Draft ALU	Trout lake	Type
Elmo	82-0106-00	0.84	E-1|14|15		P-8|7|463		2B	2Ag[TLC]	No	2A

Elmo Lake (82-0106-00): Elmo Lake is currently designated Class 2B and it is not designated for the protection of any coldwater fish species. Cisco are not native to this lake but were introduced around 1878. Cisco were extirpated in the 1930s due to drought and stocked again in 1996, 1997, and 1998. Eight MNDNR fisheries surveys conducted on Elmo Lake sampled Cisco indicating that Cisco have been established and that this lake supports a population of this species. Lake Trout were stocked in 2006 and 15 fish were sampled the same year. These fish were stocked fish and additional sampling has not sampled Lake Trout indicating poor survival and a lack of a self-sustaining population. As a result of this information, it is reasonable to designate Elmo Lake a Class 2Ag for the protection of coldwater aquatic life and habitat and assign protections for Cisco (Class 2Ag [TLC]).

7. Lower Mississippi River basin

a. Mississippi River - Lake Pepin watershed (07040001)

No draft use designations or confirmations

b. Cannon River watershed (07040002)

No draft use designations or confirmations

c. Mississippi River - Winona watershed (07040003)

No draft use designations or confirmations

d. Zumbro River watershed (07040004)

No draft use designations or confirmations

e. Mississippi River - La Crescent watershed (07040006)

No draft use designations or confirmations

f. Root River watershed (07040008)

No draft use designations or confirmations

g. Mississippi River - Reno watershed (07060001)

No draft use designations or confirmations

h. Upper Iowa River watershed (07060002)

No draft use designations or confirmations

8. Cedar-Des Moines Rivers basin

a. Upper Wapsipinicon River watershed (07080102)

No draft use designations or confirmations

b. Cedar River watershed (07080201)

No draft use designations or confirmations

c. Shell Rock River watershed (07080202)

No draft use designations or confirmations

d. Winnebago River watershed (07080203)

No draft use designations or confirmations

e. Des Moines River – Headwaters watershed (07100001)

No draft use designations or confirmations

f. Lower Des Moines River watershed (07100002)

No draft use designations or confirmations

g. East Fork Des Moines River watershed (07100003)

No draft use designations or confirmations

9. Missouri River basin

a. Upper Big Sioux River watershed (10170202)

No draft use designations or confirmations

b. Lower Big Sioux River watershed (10170203)

No draft use designations or confirmations

c. Rock River watershed (10170204)

No draft use designations or confirmations

d. Little Sioux River watershed (10230003)

No draft use designations or confirmations

Appendix D: Polymictic lakes potentially supporting coldwater fishes

The current research was focused on developing protective standards for coldwater fishes in dimictic lakes and documenting which lakes support these coldwater fishes. However, there are some polymictic lakes in Minnesota that support resident populations of Cisco or Lake Whitefish. The environmental requirements for the maintenance of these fish populations are not fully understood and these lakes were not a focus of this research. However, it is apparent that the application of WQS developed for dimictic lakes are not appropriate for polymictic lakes because many polymictic lakes that support coldwater fishes do not meet the draft criteria for dimictic lakes. Using the same analysis approach in the "***Assessment of implementation outcomes***" section, 43% of polymictic Cisco lakes and 89% of polymictic Lake Whitefish lakes did not meet either the draft T_{DO3} or chl-*a* thresholds. These rates are considerably higher than for dimictic lakes indicating that different measures are likely required to develop protective water quality standards for these lakes. This is beyond the scope of this study, but this is an area of research that should be pursued in future efforts. Although, the current research does not provide thresholds for the protection of these lakes, a list of polymictic lakes which potentially support coldwater fish species is included below (Table 57). Other than a determination that these lakes do not appear to have oxythermal conditions and habitat typical of coldwater lakes due to natural characteristics, the status of the coldwater fish in these lakes has not been fully reviewed. For example, some of these lakes may have transient populations of coldwater fishes which would exclude them from a coldwater habitat designation. This list serves to document why these lakes were not included in the list of coldwater habitats in Appendix C and identifies lakes where additional research may be needed to protect these populations of coldwater fishes.

Table 57. List of polymictic lakes which may support populations of Cisco or Lake Whitefish.
Abbreviations: HUC 8 = 8-digit hydrologic unit code; WID = water body identification code; GR = geometry ratio; LKW = Lake Whitefish; TLC = Cisco. Abbreviations and fisheries survey codes are described in the introduction of Appendix C.

HUC8	Lake name	WID	LAT	LKW	TLC
7010101	Campbell	04-0196-00	4.82		P-9|1|160
7010101	George	29-0216-00	4.82		U-9|4|37
7010102	Lower Trelipe	11-0129-00	4.06		P-11|1|285
7010102	Woman	11-0201-00	3.76		P-19|0|1005
7010103	Split Hand	31-0353-00	4.68	M-1|16|1	P-17|0|902
7010104	Lower Mission	18-0243-00	4.99		E-2|6|22
7010106	Eighth Crow Wing	29-0072-00	4.11		P-10|0|143
7010106	First Crow Wing	29-0086-00	8.34		P-11|0|42
7010106	Lower Twin	80-0030-00	4.36		P-5|4|10
7010106	Roy	18-0398-00	4.24		P-5|2|21
7010108	Mary	21-0092-00	5.41		P-15|1|355
7010207	Mille Lacs	48-0002-00	14.15	U-0|28|0	P-28|0|14826
7020005	Minnewaska	61-0130-00	7.73		U-7|9|76
9020103	Blanche	56-0240-00	2.45		P-8|1|71
9020103	Cotton	03-0286-00	6.07		P-10|0|192
9020103	Deer	56-0298-00	4.61		U-6|4|21

HUC8	Lake name	WID	LAT	LKW	TLC
9020103	Floyd	03-0387-00	4.49		U-8|2|69
9020103	Hoot	56-0782-00	4.69		U-5|3|18
9020103	Little Pelican	56-0761-00	4.56		U-4|1|67
9020103	Maud	03-0500-00	4.15		U-6|5|113
9020103	Melissa	03-0475-00	3.99		P-11|0|284
9020103	North Lida	56-0747-01	4.69		P-16|0|640
9020103	Prairie	56-0915-00	6.98		U-3|7|21
9020103	Rush	56-0141-00	3.26	U-0|14|0	P-14|0|781
9020103	Sallie	03-0359-00	3.12		P-7|4|257
9020103	Walker	56-0310-00	4.42		U-8|1|178
9020302	Blackduck	04-0069-00	6.70	P-10|2|83	M-1|11|1
9020302	Red (Upper Red)	04-0035-01	13.90	U-19|13|169	
9030001	Agnes	69-0223-00	4.96		P-2|0|140
9030001	Bald Eagle	38-0637-00	4.32	U-1|2|1	P-3|0|105
9030001	Birch	38-0532-00	3.34	U-7|3|10	P-10|0|392
9030001	Birch	69-0003-00	9.68		P-17|0|1647
9030001	Boot	69-0100-00	4.08		U-1|0|64
9030001	Crab	16-0357-00	4.57		E-5|3|62
9030001	Ensign	38-0498-00	5.34		U-3|0|539
9030001	Fall	38-0811-00	5.62	U-6|10|28	P-16|0|1366
9030001	Four	38-0528-00	5.34	P-2|0|18	P-2|0|6
9030001	Fourtown	38-0813-00	6.12		U-2|0|333
9030001	Horse	38-0792-00	5.38		U-2|0|43
9030001	Isabella	38-0396-00	8.67	P-9|0|419	
9030001	Kabetogama	69-0845-00	6.41	U-11|18|16	P-29|0|1955
9030001	Koma	38-0098-00	7.45	P-2|0|54	U-1|1|19
9030001	Little Gabbro	38-0703-00	3.74		P-3|0|67
9030001	Little Johnson	69-0760-00	4.55	P-5|3|21	
9030001	Perent	38-0220-00	4.36	P-4|1|306	M-1|4|95
9030001	Silver Island	38-0219-00	9.69	P-10|0|256	
9030001	Splash	38-0531-00	4.51		P-2|0|104
9030001	T	38-0066-00	7.21	P-6|2|121	
9030001	White Iron	69-0004-00	4.17	U-10|11|21	P-20|1|2210
9030005	Little Sturgeon	69-1290-00	4.82		P-6|0|70
9030006	Bowstring	31-0813-00	8.01	M-1|10|1	P-11|0|191
9030006	Island	31-0913-00	5.21		P-13|0|714
9030006	Little Turtle	31-0779-00	4.03		P-8|0|223
9030009	Lake of the Woods[25]	39-0002-00	3.64	P-14|20|158	P-26|8|24806

[25] Lake Trout occur on the Canadian side of Lake of the Woods, but this species has not been sampled on the United States side of this lake. Based on available information, suitable lake trout habitat is not present on the Minnesota side of Lake of the Woods and therefore will not be designated lake trout habitat.

Appendix E: Lakes reviewed for coldwater designation

In addition to the lakes listed for designation in Appendix C and the polymictic lakes in Appendix D, there are other lakes that were reviewed because coldwater fish were sampled in surveys or there was past stocking of one or more coldwater fish species (Lake Trout, Lake Whitefish, or Cisco). These lakes did not meet the criteria for consideration as coldwater habitat or the available data were deemed to be insufficient for designation. The following table documents the lakes which have been reviewed as part of this process. The inclusion on this list does not indicate that these lakes will not be designated in a future rule. In some cases, these lakes did indicate some coldwater potential, but additional data will be required to determine if a coldwater designation is appropriate and which species should be protected under such a designation.

Table 58. List of lakes which are not included for coldwater designation (Appendix C) and are not identified as polymictic lakes possibly supporting coldwater fish (Appendix D), but from which coldwater fish were sampled during MNDNR fisheries surveys. Abbreviations: HUC 8 = 8-digit hydrologic unit code; WID = water body identification code; LAT = Lake Trout; LKW = Lake Whitefish; TLC = Cisco.

HUC8	Lake name	WID	LAT	LKW	TLC
4010101	Mid Cone	16-0391-00	X		
4010101	South Temperance	16-0457-00			X
4010101	Sawbill	16-0496-00			X
4010101	Dyers	16-0634-00			X
4010201	Embarrass	69-0496-00			X
4010201	Bass	69-0553-00			X
4010201	Burns Pit	69-1378-00			X
4010202	Island Lake Reservoir	69-0372-00			X
4010301	Hay	09-0010-00			X
7010101	Swenson	04-0085-00			X
7010101	Three Island	04-0134-00			X
7010101	Irving	04-0140-00		X	X
7010101	Carr	04-0141-00			X
7010101	Little Turtle	04-0155-00			X
7010101	Black	04-0157-00			X
7010101	Fox	04-0162-00			X
7010101	Bootleg	04-0211-00			X
7010101	Little Vermillion	11-0030-00			X
7010101	Frontenac	29-0241-00			X
7010101	Hattie	29-0300-00			X
7010101	South Sugar	31-0555-00			X
7010101	Blackwater	31-0561-00			X
7010101	Fawn	31-0609-00			X
7010101	Little Moose	31-0610-00			X
7010101	Little Rice	31-0716-00			X
7010101	Dixon	31-0921-00			X

HUC8	Lake name	WID	LAT	LKW	TLC
7010102	Birch	11-0412-00			X
7010102	Fifth	11-0466-00			X
7010102	Anway	11-0469-00			X
7010102	Unnamed	11-0866-00			X
7010103	Aitkin	01-0040-00			X
7010103	Little Thunder	11-0061-00			X
7010103	Island	31-0217-00			X
7010103	Lawrence	31-0231-00			X
7010103	Little Split Hand	31-0341-00			X
7010103	Scrapper	31-0345-00			X
7010103	Prairie	31-0384-00			X
7010103	Middle Hanson	31-0396-00			X
7010103	Blandin	31-0533-00			X
7010104	Ripple	01-0146-00		X	X
7010104	Hanging Kettle	01-0170-00			X
7010104	Hickory	01-0179-00			X
7010104	Long / Tame Fish	18-0002-00			X
7010104	Maple	18-0045-00		X	
7010104	Portage	18-0069-00		X	X
7010104	Serpent	18-0090-00			X
7010104	Rabbit (West Portion)	18-0093-02			X
7010104	Roe Mine	18-0119-00			X
7010104	Clinker	18-0131-00			X
7010104	Rice	18-0145-00		X	
7010105	Mule	11-0047-00			X
7010105	Lind	11-0367-00			X
7010105	Pug Hole	18-0209-00			X
7010105	Blue	18-0211-00			X
7010105	Goggle	18-0223-00			X
7010105	Pine	18-0261-00		X	
7010105	Little Star	18-0360-00			X
7010105	Arrowhead	18-0366-00		X	
7010106	Ray	11-0220-00			X
7010106	Sylvan	11-0304-00			X
7010106	Fawn	18-0397-00			X
7010106	Nisswa	18-0399-00			X
7010106	Buck	29-0206-00			X
7010106	Bad Axe	29-0208-00			X
7010106	Hinds	29-0249-00			X
7010108	Jessie	21-0055-00			X
7010201	Little Rock	05-0013-00		X	
7010201	Platte	18-0088-00			X
7010201	Round	49-0019-00			X

HUC8	Lake name	WID	LAT	LKW	TLC
7010201	Big Spunk	73-0117-00			X
7010201	Lower Spunk	73-0123-00			X
7010202	Zumwalde	73-0089-00			X
7010202	Cedar Island	73-0133-00			X
7010202	Long	73-0139-00			X
7010202	Horseshoe	73-0157-00			X
7010202	Little Sauk	77-0164-00		X	
7010202	Lily	77-0358-00			X
7010203	Caroline	86-0281-00			X
7010204	Rice	73-0196-00			X
7030003	Bear	09-0034-00			X
9020103	Height of Land	03-0195-00			X
9020103	Siverson	56-0180-00			X
9020103	Boedigheimer	56-0212-00			X
9020103	Fischer	56-0247-00			X
9020103	Tenter	56-0348-00			X
9020103	Graham	56-0368-00			X
9020103	East Lost	56-0378-00			X
9020103	West Lost	56-0481-00			X
9020103	Elbow	56-0514-00			X
9020103	Big Crow	56-0576-00			X
9020103	Orwell	56-0945-00			X
9020302	Myrtle	04-0304-00		X	
9020302	Sandy	04-0307-00		X	
9030001	Clove	16-0581-00		X	
9030001	Romance	16-0630-00			X
9030001	Zephyr	16-0813-00		X	
9030001	Granite Bay	16-0900-00		X	
9030001	Fish	38-0161-00		X	
9030001	Kekekabic Pond 2	38-0188-02	X		
9030001	Annie	38-0195-00		X	
9030001	Sagus	38-0225-00			X
9030001	Hatchet	38-0369-00			X
9030001	Shepo	38-0373-00			X
9030001	Alworth	38-0401-00			X
9030001	Cache	38-0477-00			X
9030001	Greenstone	38-0718-00			X
9030001	Stub	38-0781-00			X
9030001	Moosecamp	38-0816-00			X
9030001	One Pine	69-0061-00			X
9030001	Little Sletten	69-0086-00			X
9030001	East Twin	69-0174-00		X	
9030001	Thumb	69-0337-00			X

HUC8	Lake name	WID	LAT	LKW	TLC
9030002	Eagles Nest #1	69-0285-01	X		
9030005	Shannon	69-0925-00			X
9030006	Tank	31-0188-00			X
9030006	Battle	31-0197-00			X
9030006	Unnamed	31-0338-00			X
9030006	Mink	31-0455-00			X
9030006	Oar	31-0464-00			X
9030006	Aspen	31-0690-00			X
9030006	Lundeen	31-0705-00			X
9030006	Little Too Much	31-0778-00			X
9030006	Little Spring	31-0797-00			X
9030006	Dora	31-0882-00			X
9030006	Shallow Pond	31-0910-00		X	X
9030006	Hamrey	31-0911-00			X
9020302	Julia	04-0166-00	X		
9020302	Dark	04-0167-00	X		
9020302	Island	04-0265-00	X		
7010105	Norway	11-0307-00			X
7010102	Fourth	11-0465-00			X
7010104	Hamlet	18-0070-00			X
7010104	Eagle	18-0099-00			X
7010105	Trout	18-0218-00			X
7010102	Oak	29-0060-00			X
7010103	Bass	31-0115-00	X		
9030005	Bear	31-0157-00			X
7010103	Blackberry	31-0210-00	X		
7010103	Mountain Ash	31-0531-00	X		
7010103	Spider	31-0538-00			X
4010101	Hare	38-0026-00	X		
4010101	Ninemile	38-0033-00	X		
9030001	Gerund	38-0366-00	X		X
9030001	Wind	38-0642-00			X
7010104	Pine	49-0081-00			X
9020103	Leek (Trowbridge)	56-0532-00			X
7030001	Razor	58-0010-00	X		
7030001	Greigs	58-0013-00	X		
7030001	Lena	58-0018-00	X		
7030001	Tamarack	58-0024-00	X		
7030003	Sturgeon	58-0067-00	X		
9020305	Spring	60-0012-00	X		
9020301	Union	60-0217-00	X		
7020005	Linka	61-0037-00			X
9030001	Muckwa	69-0159-00	X		

HUC8	Lake name	WID	LAT	LKW	TLC
9030001	Little Hustler	69-0332-00	X		
4010201	Lower Comstock	69-0412-02			X
9030002	Black	69-0740-00	X		
4010201	St. Louis River Estuary	69-1291-00			X
4010201	Iron Chief Complex	69-1428-00	X		
7010202	Deep	73-0141-00			X
7010202	Big	73-0159-00			X

November 2026

Development of a Tiered Aquatic Life Use Framework for Minnesota Lakes

Based on fish index of biological integrity scores and thresholds.



MINNESOTA

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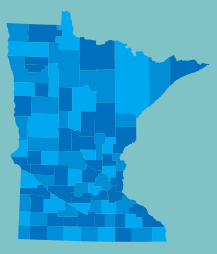
Department of Natural Resources



wq-bsm4-03

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Document number: wq-bsm4-03

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Acronyms or abbreviations

1W1P	One Watershed One Plan
2A	Aquatic Life and Recreation – Coldwater Aquatic Life and Habitat
2Ae	Aquatic Life and Recreation – Exceptional Use Coldwater Aquatic Life and Habitat
2Ag	Aquatic Life and Recreation – General Use Coldwater Aquatic Life and Habitat
2B	Aquatic Life and Recreation – Cool and Warm Water Aquatic Life and Habitat
2Be	Aquatic Life and Recreation – Exceptional Use Cool and Warm Water Aquatic Life and Habitat
2Bg	Aquatic Life and Recreation – General Use Cool and Warm Water Aquatic Life and Habitat
BCG	Biological Condition Gradient
BWSR	Board of Water and Soil Resources
CWA	Clean Water Act (33 U.S.C. § 1251 et seq.)
DOW	Division of Waters number
EPA	U.S. Environmental Protection Agency
FIBI	Fish-based Index of Biological Integrity
FMA	Fisheries Management Area
FQI	Floristic Quality Index
GAM	Generalized additive model
HUC 8	8-digit Hydrological Unit Code
IBI	Index of Biological Integrity
IWM	Intensive Watershed Monitoring
LAT	Lake Trout
LGU	Local Government Unit
LKW	Lake Whitefish
LOBS	Lakes of Biological Significance
MBS	Minnesota Biological Survey
Minn. R.	Minnesota Rules
Minn. Stat.	Minnesota Statutes
MN	Minnesota
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NPDES	National Pollutant Discharge Elimination System
NLCD	National Land Cover Database
SID	Stressor Identification
SRT	Stream Trout spp.
TALU	Tiered Aquatic Life Uses
TLC	Cisco (Tullibee)
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
U.S.C.	United States Code
WID	Waterbody identification number (Minnesota Pollution Control Agency)
WQS	Water Quality Standards
WRAPS	Watershed Restoration and Protection Strategy

Definitions

The following definitions of terms used in this document are based on standard use and are provided for the convenience of the reader. Unless otherwise specified, these definitions are specific to this document.

Antidegradation: The element of state water quality standards (WQS) that protects and maintains existing uses, prevents degradation of high-water quality unless certain conditions are met, and which protects and maintains the quality of outstanding resource waters.

Aquatic Biota: The aquatic community composed of game and nongame fish, minnows and other small fish, mollusks, insects, crustaceans and other invertebrates, submerged or emergent rooted vegetation, suspended or floating algae, substrate-attached algae, microscopic organisms, and other aquatic-dependent organisms that require aquatic systems for food or to fulfill any part of their life cycle, such as amphibians and certain wildlife species. See Minn. R. 7050.0150, subp. 4.

Aquatic Life Use: A designated use that protects aquatic biota including fish, insects, mollusks, crustaceans, plants, microscopic organisms and all other aquatic-dependent organisms. Attainment of aquatic life uses are measured directly in Minnesota using Indices of Biological Integrity (IBIs) and biological criteria. Chemical and physical standards are also used to protect aquatic life uses.

Aquatic Life Use Goals: A goal for the condition of aquatic biota; required by the Clean Water Act (CWA). Minimum aquatic life use goals are established using the CWA interim goal ("…water quality which provides for the protection and propagation of fish, shellfish, and wildlife…"). The objectives for these goals are established in Minnesota Rule using narrative standards, numeric standards, or both. Attainment of these goals is directly measured in Minnesota using IBIs and associated "Biological Criteria" or "Biocriteria."

Assemblage: A taxonomic subset of a biological community such as fish in a stream community. See Minn. R. 7050.0150, subp. 4.

Beneficial Use: A designated use described under Minn. R. 7050.0140 and listed under Minn. R. 7050.0400 to Minn. R. 7050.0470 for each surface water or segment thereof, whether or not the use is being attained. (The term "designated use" may be used interchangeably.) See also "Existing Use."

Biological Assessment: An evaluation of the biological condition of a water body using surveys of the structure and function of an assemblage of resident biota. It also includes the interdisciplinary process of determining condition and relating that condition to chemical, physical, and biological factors that are measured along with the biological sampling. Guidance for performing biological assessments in Minnesota is described in MPCA (2018a; https://www.pca.state.mn.us/sites/default/files/wq-iw1-04j.pdf). (The term "bioassessment" may be used interchangeably.)

Biological Condition Gradient (BCG): A concept describing how aquatic communities change in response to increasing levels of stressors. In application, the BCG is an empirical, descriptive model that rates biological communities on a scale from natural to highly degraded.

Biological Criteria,[1] Narrative or Biocriteria, Narrative: Written statements describing the attributes of the structure and function of aquatic assemblages in a water body necessary to protect the designated aquatic life beneficial use. See Minn. R. 7050.0150, subp. 4.

[1] The term "biological criteria" can be used interchangeably with "biological standard." Minnesota rule uses the term "standard" to mean "*a number or numbers established for a pollutant or water quality characteristic to protect a specified*

Biological Criteria,[1] **Numeric or Biocriteria, Numeric:** Specific quantitative measures of the attributes of the structure and function of aquatic communities in a water body necessary to protect the designated aquatic life beneficial use. See definition in Minn. R. 7050.0150, subp. 4.

Biological Integrity: The condition where "the biota is a balanced, integrated, adaptive system having a full range of ecosystem elements (genes, species, assemblages) and processes (mutation, demographics, biotic interactions, nutrient and energy dynamics, metapopulation dynamics) expected in areas with no or minimal human influence" (after Karr 2000).

Biological Monitoring: The measurement of a biological entity (taxon, species, assemblage) as an indicator of environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods. (The term "biomonitoring" may be used interchangeably.)

Clean Water Act (CWA): An act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). 33 U.S.C. § 1251 et seq.

Criteria: Narrative descriptions or numerical values which describe the chemical, physical, or biological conditions in a water body necessary to protect designated uses. See also the definitions for "biological criteria/biocriteria" and "standard".

Designated Use: See "beneficial use."

Division of Waters number (DOW): The Minnesota Department of Natural Resources (MNDNR) assigns lakes a unique Division of Waters numbers (DOW) which are used to identify assessment units and track management efforts. DOWs are also used to assign and track designated uses. Numbering follows the format of XXYYYYZZ where XX is a county code (alphabetically assigned), YYYY is a random, unique basin number in that county, and ZZ is the sub-basin or embayment number. These numbers are referred to as waterbody identification numbers (WID) or assessment unit identification numbers (AUID) by the Minnesota Pollution Control Agency (MPCA). The composition of these identification numbers is similar for the MPCA and MNDNR. The only difference is the MPCA includes hyphens between the county code, basin number, and embayment number. For example, the lake identification number used by the MPCA could be "01-0001-00" and for the same lake the MNDNR will use "01000100."

Existing Use: Those uses actually attained in the surface water on or after November 28, 1975. See definition in Minn. R. 7050.0255, subp. 15.

Fish 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.

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

Standard: Regulatory limits on a particular pollutant, or a description of the condition of a water body, presumed to support or protect the beneficial use or uses. Standards may be narrative or numeric and

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beneficial use" (Minn. R. 7050.0218, subp. 3). The EPA's use of the term "criteria" is similar to Minnesota's use of "standard." "Biological criteria" and "biocriteria" are the terms most used in the United States to refer to numerical values, which represent the biological condition or health necessary to protect designated uses. Using Minnesota rule terminology, these values would be called "biological criteria" or "biocriteria" before promulgation and "biological standards" following promulgation in rule. However, to be consistent with the terminology used by federal agencies and by other states and tribes, the terms "biological criteria" and "biocriteria" are used in this document and in rule to refer to both the promulgated and unpromulgated values.

are commonly expressed as a chemical concentration, a physical parameter, or a biological assemblage endpoint. See also the definitions for “biological criteria/biocriteria” and “criteria”.

Stressors: Physical, chemical, and biological factors that can adversely affect aquatic organisms. The effect of stressors is apparent in biological responses because stressor conditions are outside the conditions for which an organism is adapted. This leads to changes in the fitness of organisms and changes in the composition of organisms found in aquatic communities. Under the effect of stressors, the normal functioning of organisms is disturbed (e.g., increased metabolism, interruption of behavior) which results in negative impacts such as decreased fitness, reduced growth, increased disease prevalence, interruption of reproductive behavior, increased emigration, and increased mortality. Examples of stressors in aquatic systems are excess nutrients, physical habitat alteration, altered interspecific competition, low dissolved oxygen, and increased temperature regimes.

Tiered Aquatic Life Uses: Tiered aquatic life uses or TALUs are designated uses assigned to water bodies based on their ecological potential and the ability to protect or restore a water body to that attainable level. This means that the assignment of a TALU tier to a specific water body is done based on reasonable restoration or protection expectations and attainability. Knowledge of the current condition of a water body and an accompanying and adequate assessment of stressors affecting that water body are needed to make these assignments.

Tiered Aquatic Life Use Framework: A TALU framework is the structure of designated aquatic life uses that incorporates a hierarchy of use subclasses. The TALUs in a TALU framework are based on representative ecological attributes reflected in the narrative description of each TALU tier and embodied in the measurements that extend to expressions of that narrative through numeric biological criteria and, by extension, to chemical and physical indicators, and standards.

Total Maximum Daily Load: The maximum amount of a pollutant that a body of water can receive while still meeting WQS. Alternatively, a TMDL is an allocation of a water pollutant deemed acceptable to still attain the beneficial use assigned to the water body. See 40 CFR § 130.7.

Water Quality Standards (WQS): A law or regulation that consists of the beneficial use or uses of a water body, the narrative or numerical WQS that are necessary to protect the use or uses of that particular water body, and antidegradation.

A. Overview

The Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Natural Resources (MNDNR) have developed revisions to Minnesota's water quality rules for determining aquatic life use condition in lakes. The goal of the draft rule revisions is to establish a framework for assessing fish community health which will improve protections for biological communities and their habitats in Minnesota lakes. The draft rule revisions will implement a Tiered Aquatic Life Use (TALU) framework for classifying lakes based on their highest attainable aquatic life use. This draft framework is similar to the framework currently used to assess Minnesota streams. Currently, General Use[2] biocriteria are used as numeric translators for narrative standards to determine biological impairments for lakes based on their fish communities. These amendments would add an Exceptional Use tier with associated biocriteria for lakes with diverse and unique fish communities, as indicated by a high fish index of biological integrity (FIBI) score. Numerous lakes, both in watersheds with minimal human disturbance and in watersheds with increasing human disturbance, currently have exceptional fish communities, and would benefit from a TALU approach. Adding Exceptional Use biocriteria will limit the amount of degradation that can occur in high quality lakes before remediation is needed. In addition, the TALU framework will continue to identify lakes with degraded fish communities that do not meet Clean Water Act (CWA) minimum goals (i.e., do not meet General Use goals) and to guide restoration and protection activities for lakes that do not support exceptional fish communities.

Adoption of a TALU framework for lakes in Minnesota will meet the following needs:

1. Incorporate subcategories or tiers into the aquatic life beneficial use (Class 2) classification to address the diversity of lake resources in Minnesota. Minnesota's aquatic resources are varied and diverse and the existing "one-size-fits-all" approach fails to recognize critical differences, which can result in less effective management of these waters. The TALU framework results in attainable and appropriate goals for aquatic life beneficial uses in lakes. It is consistent with the concept of protecting existing uses while simultaneously providing higher goals for waters with demonstrated exceptional biological quality and maintaining current goals for General Use waters. To accomplish this, Class 2 aquatic life beneficial uses will be refined for lakes by the addition of Exceptional and General use tiers to the Class 2 designation. These tiers are described as follows:
    - Exceptional Use: Exceptional Use lakes are those that are near natural or undisturbed conditions. There is a need to protect and maintain high-quality lakes in Minnesota. Establishing an Exceptional Use tier will help ensure that existing water quality rules, such as antidegradation, can adequately protect high quality lakes.
    - General Use: The General Use maintains the current default aquatic life use goal (Class 2B). These waters support good biological communities consistent with the CWA's interim goal (i.e., "…water quality which provides for the protection and propagation of fish, shellfish, and wildlife…").
2. Improve standards by incorporating numeric biological criteria directly into rule. Water quality standards (WQS) can be either narrative or numeric. Narrative standards describe water quality conditions that are not allowed because the conditions negatively affect beneficial uses (e.g., "the species composition shall not be altered materially" Minn. R. 7050.0150, subp. 3). Numeric standards establish numeric thresholds for pollutants that, when violated, indicate a polluted

[2] Although not currently defined as "General Use" in Minnesota rule, the current protections for aquatic life in lakes under Class 2 are equivalent to the draft General Use.

condition (e.g., a minimum of 5 mg/L of dissolved oxygen). The MPCA currently uses biological criteria to quantitatively translate the narrative biological standards in Minn. R. 7050.0150, subp. 3. The TALU framework brings biological criteria directly into rule as a clear numeric standard. Numeric biological criteria stratified by lake type and TALU will be added to Minn. R. 7050.0222 to clarify the biological expectations for Minnesota's lakes. Such added clarity about biological expectations provides greater certainty to stakeholders and regulated parties. The draft TALU biological criteria for Minnesota lakes consist of General Use biological criteria for four lake types and Exceptional Use biological criteria for two lake types.

3. Create more clarity in rule by documenting the methods used to establish biological conditions and biological criteria. For clarity, consistency in application, and transparency, the draft TALU framework amendments include descriptions of each tiered aquatic life use (i.e., Exceptional and General). These revisions will also provide an explanation of the specific scientific methods used to measure biological condition and derive the biological criteria. This includes documentation of the development of Minnesota's FIBI and the Biological Condition Gradient (BCG), which together support biological condition determinations and biological criteria.
4. Improve targeting of water management resources. Biological assessments are used to make decisions about water quality management activities. Greater assessment accuracy leads to increased water quality management efficiency because resources are not used to restore waters beyond what is currently attainable nor are high quality waters under-protected. The TALU framework refines Minnesota's aquatic life use classification framework and improves the management of lakes by assigning appropriate and attainable beneficial use classifications. The TALU framework thereby recognizes the diversity of attainable conditions in Minnesota lakes so that management of these waters can be focused on managing these lakes to their highest attainable condition. This results in better use of protection and restoration resources with a goal of maintaining and improving conditions.
5. Designation of a subset of Exceptional Use lakes. A subset of lakes monitored as part of the Intensive Watershed Monitoring (IWM) framework will be reclassified where adequate existing monitoring data has demonstrated that the lake meets or met the Exceptional Use goals for fish on or after November 28, 1975. This subset of lakes provides a demonstration of how the MPCA will document these types of changes in future rulemakings and the type of data necessary to support future proposals. The MPCA intends to make future TALU proposals periodically following the IWM schedule or as needed. These future rule changes will follow the Minnesota Administrative Procedures Act (APA).

B. Introduction

Minnesota currently uses FIBI models to assess the biological condition of different lake types for attainment of aquatic life use goals. FIBIs were developed for four groups of Minnesota lakes that are deep enough to support fish populations and are between 100 and 10,000 acres (see Bacigalupi et al. 2021). The lake groups were determined using a hierarchical cluster analysis that grouped lakes by Schupp Lake Class (Schupp 1992), with similar physical features and geographic position (total area, maximum depth, percent littoral area (<4.6m or 15 ft), shoreline development index (SDI, shoreline length relative to the shoreline length of a perfectly circular lake of equal area), total alkalinity, volume, area:shoreline ratio, and growing degree days). The resulting lake groups are referred to as groups 2, 4, 5, and 7, and each FIBI is numbered to correspond to its respective lake group (i.e., FIBI 2, 4, 5, and 7, (Table 1)). Schupp Lake Class and FIBI lake group assignments for individual lakes are available on the Minnesota Geospatial Commons (DNR Hydrography–All Water Features and Lakes with DNR Fisheries IBI Scores, respectively).

Table 1. Tiered aquatic life use biological criteria for fish in Minnesota lakes (FIBI=fish index of biological integrity).

Lake group/FIBI model	Short description	Schupp Lake Classes	Exceptional Use biocriterion	General Use biocriterion
2	Deep, complex	22, 23, 24, 25, 27; can also include 20, 21, 26	64	45
4	Deep, simple	28, 29, 30, 31, 32	59	38
5	Moderately shallow, vegetated	33, 34, 35, 36, 37, 39	-	24
7	Shallow, productive	38, 40, 41, 42, 43	-	36

Lakes in Group 2 generally have the highest volume, a range of habitat types, low littoral area, seasonal thermal stratification, and consequently the highest species richness. They span a wide range of sizes and geographic locations. Group 4 lakes are also deep, often thermally stratify, are generally smaller with less complex habitats than Group 2 lakes, and are primarily located in central and northern Minnesota. Group 5 and 7 lakes range in size and are typically much shallower with lower species richness. Group 5 lakes are shallow to moderately deep, mostly littoral, and are primarily located in central and northern Minnesota. Group 7 lakes are the shallowest lakes, with over 80% of the lake area littoral and are primarily located in southern and western Minnesota.

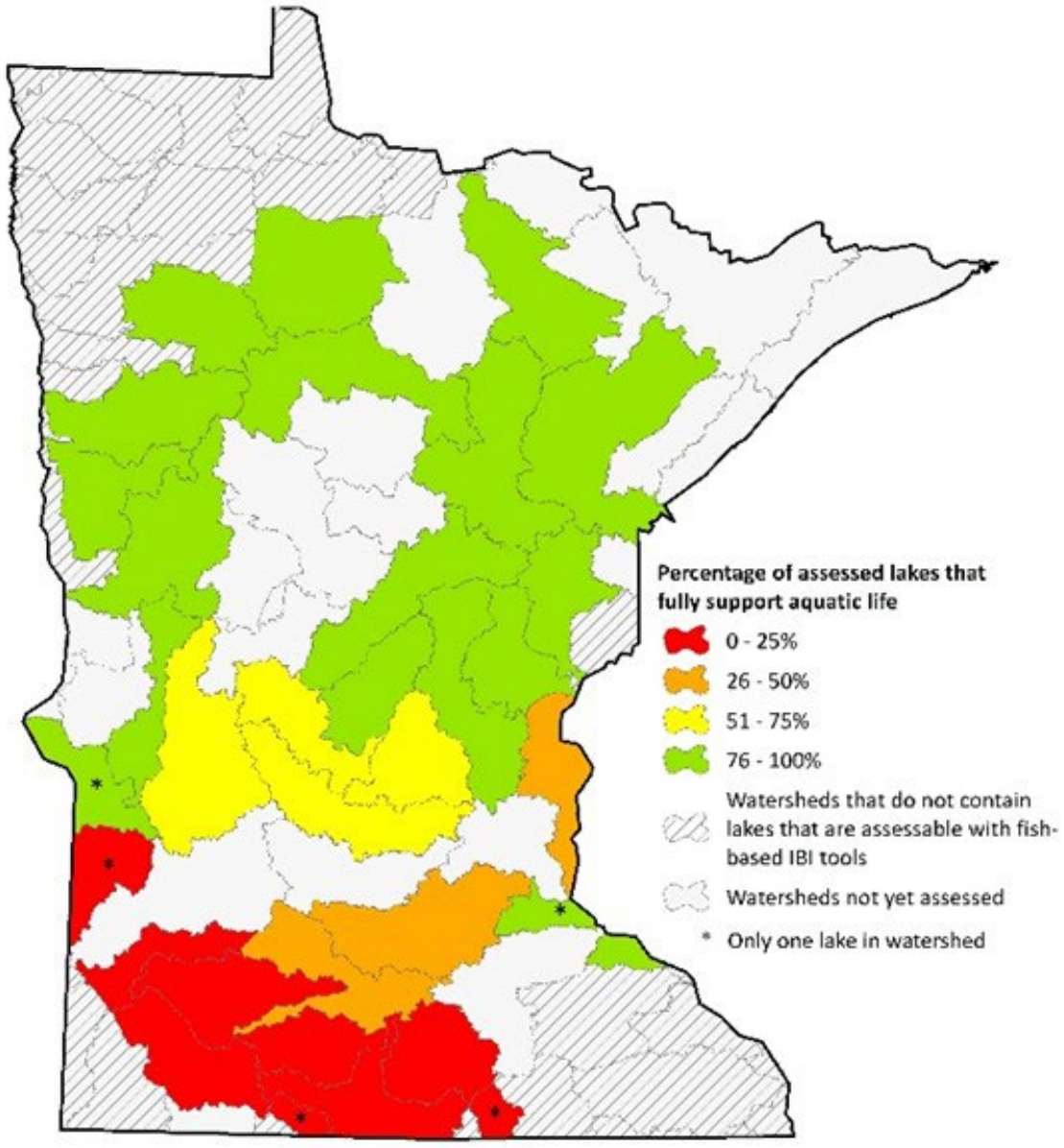
FIBIs are composed of 8 to 15 metrics, which include richness metrics and gear-specific metrics (Bacigalupi et al. 2021). Richness metrics include the number of native species or the number of species within tolerance, feeding, habitat, and family groups. Gear-specific metrics describe assemblage composition including the proportional biomass of a feeding group sampled in trap net and gill net gear types and the proportion of intolerant or habitat dependent individuals sampled with nearshore gears types (i.e., backpack electrofishing and seining) (Table 2). Metrics included in each FIBI had a significant relationship with one or more stressor variables. For richness metrics with a significant relationship to lake surface area, linear regression was used to identify the relationship, and the metric score was adjusted accordingly so that the metric response would represent differences in lake integrity rather than differences due to lake size (Bacigalupi et al. 2021). FIBI scores were calculated by summing metrics and scaling each composite FIBI from 0 – 100.

Table 2. Fish index of biological integrity (FIBI) metrics used in some or all FIBIs and the relationship with the FIBI score (from Bacigalupi et al. 2021). A "+" indicates that a higher metric value corresponds to a higher FIBI score, a "-" indicates that a higher metric value corresponds to a lower FIBI score.

FIBI metric	Relationship
Number of species captured that are native species (all gears)	+
Number of species captured that are intolerant of stressors (all gears)	+
Number of species captured that are tolerant of stressors (all gears)	-
Number of species captured that are insectivores (all gears)	+
Number of species captured that are omnivores (all gears)	-
Number of species captured that are cyprinids (all gears)	+
Number of species captured that are small benthic-dwelling (all gears)	+
Number of species captured that are vegetation-dwelling (all gears)	+
Proportion of individuals captured in the nearshore gears that are classified as intolerant of stressors	+
Proportion of individuals captured in the nearshore gears that are classified as small benthic-dwelling	+
Proportion of individuals captured in the nearshore gears that are classified as vegetation-dwelling	+
Proportion of biomass in trap nets from insectivores	+
Proportion of biomass in trap nets from omnivores	-
Proportion of biomass in trap nets from species classified as tolerant of stressors	-
Proportion of biomass in gill nets from top carnivores	+
Presence/absence of a species classified as intolerant of stressors in the gill net	+

To use the FIBIs to assess the health of Minnesota lakes, biocriteria were developed that identified impairment and exceptional thresholds for each FIBI model. BCG models for fish assemblages in Minnesota lakes were developed independently of the FIBIs to define changes to the fish communities along a gradient of increasing anthropogenic stressors (Gerritsen and Stamp 2014). The General Use impairment biocriteria have been in use since 2015 to assess the condition of 605 lakes in 33 major watersheds from 2015 – 2021 (Figure 1).

Figure 1. Percentage of lakes sampled within an assessed watershed that fully support aquatic life, as measured by fish indices of biological integrity (FIBI). Percentage calculations exclude lakes that had insufficient or inconclusive information to make an assessment decision.



Although protective of overall good fish communities, the General Use impairment biocriteria allow for loss of species and moderate changes in community structure before an impairment is identified. As a result, the General Use biocriteria do not afford protection for lakes that support unique, high quality native fish communities. Many Minnesota lakes, particularly in the northern, forested area of the state, support high biodiversity and are nearly always associated with high quality habitat required to support fish species intolerant of disturbance. Some of the species sampled are species of greatest conservation need in Minnesota (e.g., Lake Sturgeon, Least Darter, Northern Longear Sunfish, and Pugnose Shiner). The aquatic and shoreline habitats that support exceptional fish communities also often support high quality amphibian, bird, and plant communities.

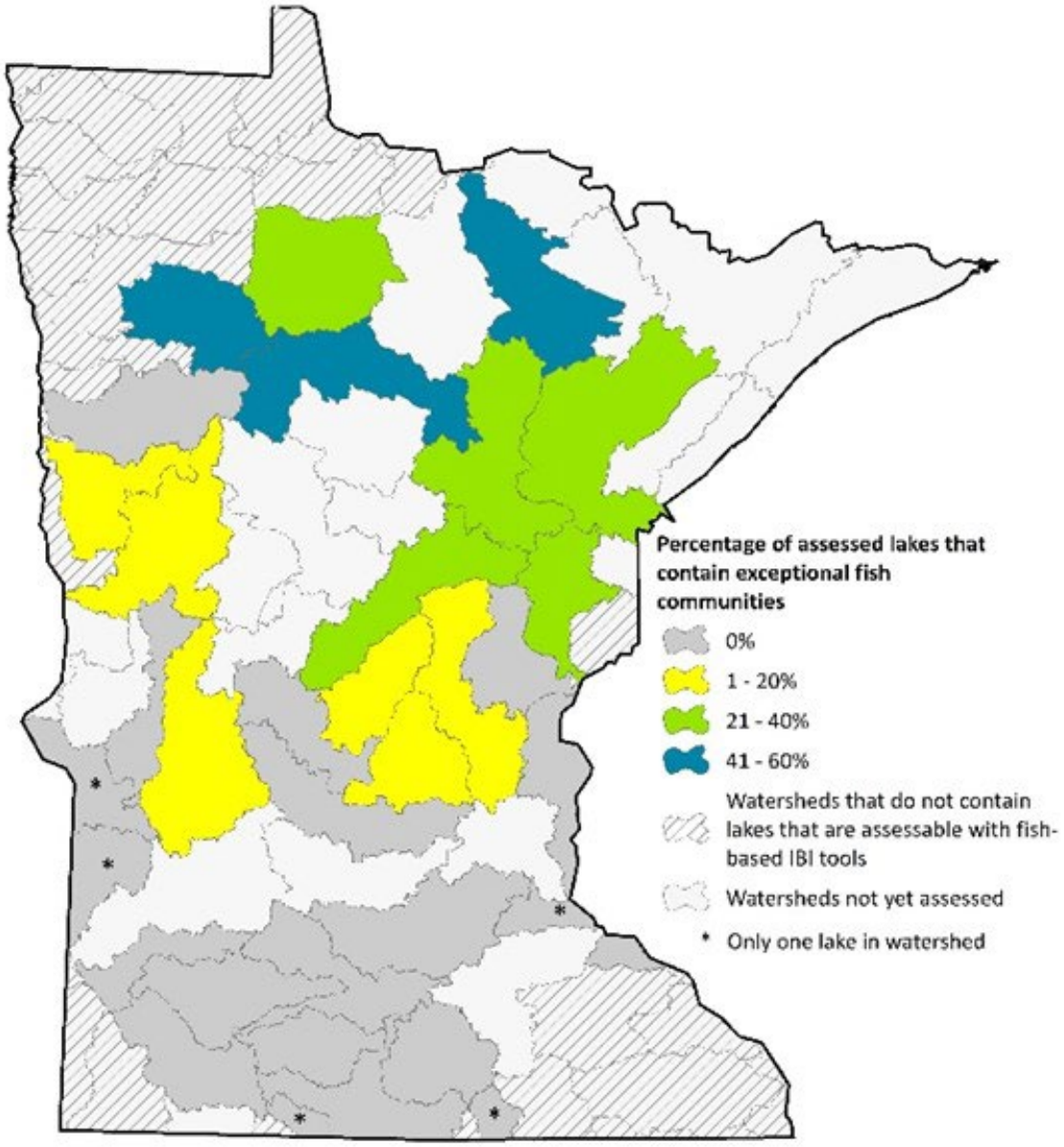
General Use impairment thresholds are developed and are in use for all FIBIs (2, 4, 5, and 7). Exceptional Use thresholds are developed for lakes scored with two of the FIBIs (FIBIs 2 and 4) and would be used in future assessments following the adoption of the lake TALU framework. Lakes with low human disturbance in Groups 2 and 4 have diverse fish communities that include species intolerant of disturbance, small benthic dwelling species, vegetation dwelling species, and often cold-water fish species. An Exceptional Use is not proposed for moderate depth and shallow lakes (FIBIs 5 and 7) because fish diversity is typically low and intolerant species are uncommon in shallow lakes, even shallow lakes with low disturbance and high-quality habitat. This is likely due to the lack of habitat complexity, lack of cold-water habitat, and naturally induced (recent or historical) partial winterkills in some shallow lakes.

An Exceptional Use designation within a TALU framework was established to protect Minnesota streams that contain exceptional fish communities from future degradation (Gerritsen et al. 2017). The approach proposed for lakes is similar, except that only two tiers have been developed for lakes: Exceptional and General Use. The TALU framework for streams also includes a Modified Use which applies to streams with legally altered habitat (e.g., many ditches and channelized streams). However, no Modified Use category was developed for lakes because there is not a widespread, analogous situation for lakes that meets the requirements (40 CFR § 131.10 (g)) for the removal of designated use specified in section 101(a)(2) of the CWA.

In this report, we summarize assessments on 605 lakes using the General Use impairment threshold and evaluate the application of an Exceptional Use impairment threshold within the TALU framework for lake with sufficient monitoring data. This includes lakes that have been assessed through 2021 and lakes surveyed using the FIBI methodology but not yet assessed. Two examples of TALU implementation are described. Example 1 considered 182 lakes sampled from 2010-2019 with one or more scores above the proposed Exceptional Use biocriteria. This large number of potentially Exceptional Use lakes highlights the importance and urgency of adopting an Exceptional Use threshold to adequately protect aquatic life in these unique, high-quality lakes that are often located in watersheds where little human disturbance has occurred, but not always protected from future disturbance. Example 2 describes three upcoming watershed assessments in lake-rich watersheds with very different landscapes and examines potential use classifications in each watershed.

The FIBIs and General Use thresholds are currently used to guide clean water planning, restoration, and protection efforts and to complement pollutant-based water quality sampling efforts in lakes as part of the Minnesota watershed assessment process. While the Exceptional Use biocriteria is not yet used as a formal category during assessment, MNDNR has been identifying lakes with FIBI scores above the draft Exceptional Use threshold for a couple of purposes since 2015 (Figure 2). Currently, lakes with scores above the proposed Exceptional Use threshold receive additional points in a scoring regime for potential MNDNR Fisheries acquisitions and are included on a list of lakes of biological significance (LOBS). The lakes with exceptionally high FIBI score and LOBS lists are provided to the Board of Water and Soil Resources (BWSR), MPCA, local government units (LGUs), and other interested parties for prioritization efforts. These results can be considered as part of Watershed Restoration and Protection Strategies (WRAPS), One Watershed One Plan (1W1P), forestry planning groups, and are also often considered during environmental review of projects impacting lakeshore and water quality. The formal adoption of the TALU framework for lakes and an Exceptional Use tier would enhance these existing programs and provide needed protections for high quality and sensitive lakes.

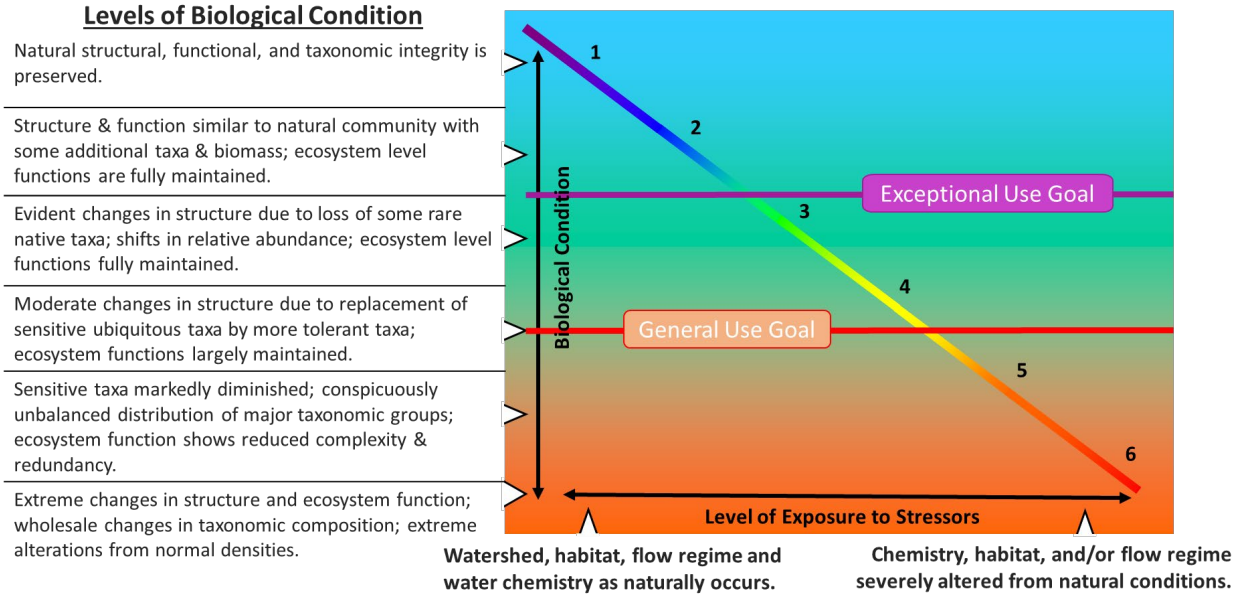
Figure 2. Percentage of lakes sampled within an assessed watershed that contain an exceptional fish community, as measured by fish indices of biological integrity. Percentage calculations exclude lakes that had insufficient or inconclusive information to make an assessment decision.



C. Development of biocriteria

Fish biocriteria for Minnesota lakes were developed by aligning BCG levels (Figure 3) with FIBI scores to determine protective thresholds for General and Exceptional uses (see Bacigalupi et al. 2021; Table 1). Lakes meeting the Exceptional Use biocriteria support fish communities that are characterized as being near the natural condition. The General Use tier applies to the remaining lakes which are characterized as having good fish communities with the function of the assemblage largely maintained although some sensitive species may have been lost and replaced by more tolerant taxa. The BCG models for Minnesota lakes were developed by Tetra Tech, Inc. with participation of aquatic biologists from MPCA, MNDNR, Midwest Biodiversity Institute, and an independent fisheries biologist (Gerritsen and Stamp 2014). Methods of calibrating BCG models and developing thresholds were similar to those used for developing biocriteria for Minnesota streams (Bouchard et al. 2016, Gerritsen et al. 2017). BCG models for each lake group were developed, calibrated, and confirmed for fish communities in lakes with FIBI survey data, and scoring for each BCG model was adjusted based on lake size (Gerritsen and Stamp 2014). FIBIs and BCG models were developed independently, and BCG assignments were compared to FIBI scores after development.

Figure 3. Biological condition gradient illustrating the location of biocriteria for protection of Minnesota's tiered aquatic life use goals for lakes.



The methodology for assigning impairment thresholds to lake TALUs was similar to the approach used for Minnesota streams (Bouchard et al. 2016). In this approach, the median of BCG Level 4 was determined to be consistent good biological condition and attainment of the CWA interim goal. The 75th percentile of BCG Level 3 was consistent with a high quality, near natural biological community. The alignment of General (BCG Level 4) and Exceptional (BCG Level 3) uses was based on identifying narrative BCG Level descriptions that best aligned with the concept of General and Exceptional uses in addition to aligning these levels to waterbodies meeting goals (i.e., reference waterbodies; Bouchard et al. 2016).

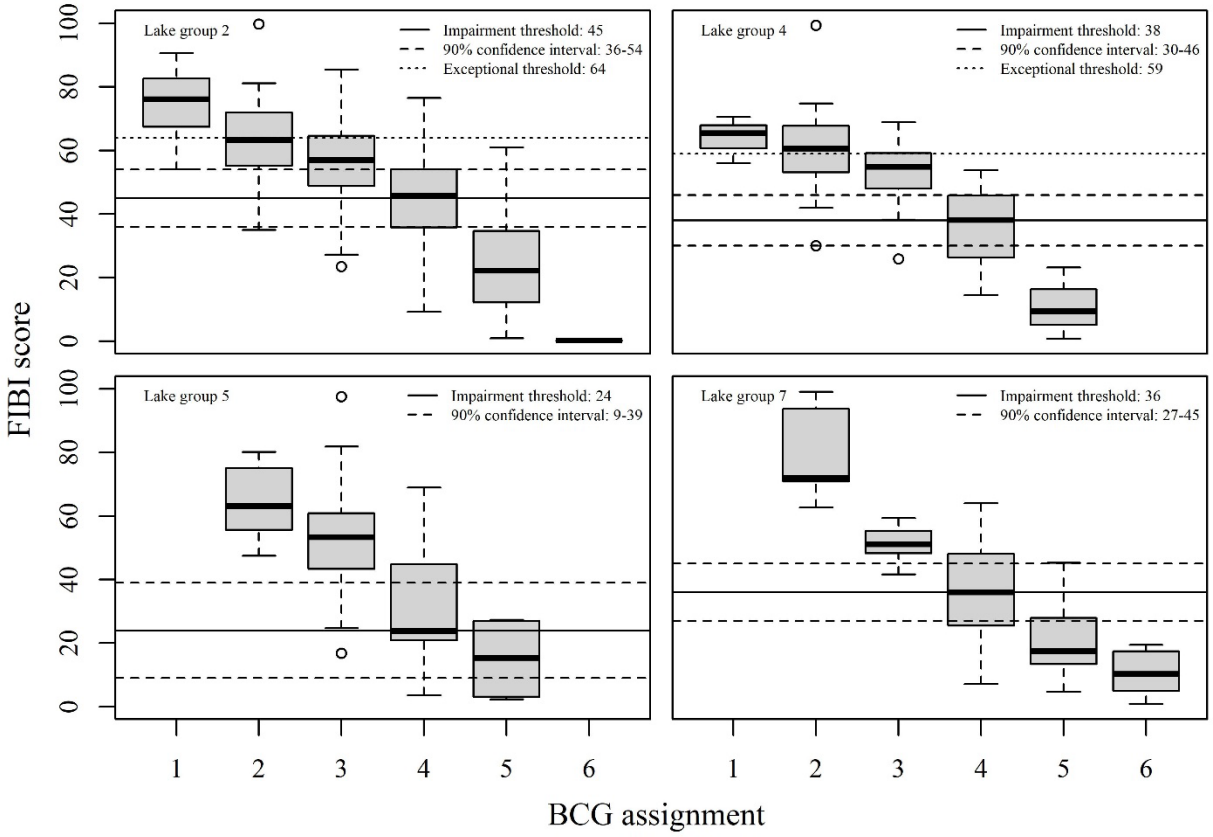
For each lake group, the FIBI score corresponding to the median of BCG Level 4 was assigned as the General Use impairment threshold (Figure 4). Lakes with FIBI scores near the General Use impairment threshold generally contained a lower diversity and proportion of intolerant species, a higher proportion

of biomass from tolerant species, and a higher proportion of biomass from omnivores relative to insectivores. These observations were consistent with the description provided by Davies and Jackson (2006), where BCG Level 4 corresponds with moderate changes in the structure of the biotic community due to replacement of some sensitive taxa by more tolerant taxa.

The proposed Exceptional Use threshold was assigned for FIBIs 2 and 4 at FIBI scores corresponding to the upper quartile of BCG Level 3, which was very similar in value to the median of BCG Level 2 (Figure 4). Lakes with FIBI scores above the Exceptional Use threshold generally contained a high number of intolerant and small benthic-dwelling species and a low number or zero tolerant species. Likewise, insectivores, top carnivores, and vegetation-dwelling species represented a large proportion of the catch in these lakes. These observations were also in alignment with the descriptions of BCG Levels 2 and 3, where either virtually all native taxa are maintained or where some changes in biotic community structure have occurred due to loss of some rare native taxa but where sensitive taxa are still common and abundant (Davies and Jackson 2006).

Repeat surveys conducted within three years were evaluated using ANOVA to calculate the 90% confidence interval around the General Use impairment threshold. The 90% confidence interval for each FIBI varied from 8 to 15 points (Figure 4). These were similar to 90% confidence intervals reported for FIBIs for Minnesota streams, which vary from 9 to 16 points, with a median of 10, on a 100-point scale (J. Sandberg, personal communication 2021).

Figure 4. Box-and-whisker plots showing the distribution of FIBI scores for each biological condition (modified from Bacigalupi et al., 2021).



D. Implementation of TALU thresholds in assessments

In Minnesota, a major (HUC 8) watershed framework is used to monitor, assess, and restore impaired waters, and to protect unimpaired waters. Monitoring and assessment of waterbodies is led by the MPCA, in collaboration with local governments, MNDNR, other state agencies, and Tribes. A comprehensive description of the Minnesota watershed approach to monitoring and assessment can be found at https://www.pca.state.mn.us/water/water-monitoring-and-assessment. Fish surveys to support biological assessment on lakes are summarized and reviewed by MNDNR Fisheries staff and used by MPCA for lake assessments in each major watershed with suitable lakes. Assessments use FIBI data to determine biological condition of lakes including the identification of impaired lakes, lakes vulnerable to future impairment, and lakes fully supporting the aquatic life use. In some cases, the FIBI survey data is inconclusive or insufficient for an assessment determination. Currently, lakes of exceptional biological quality with scores above the proposed Exceptional Use threshold are identified but are held to the General Use impairment threshold.

1. Biological survey methodology

MNDNR staff use four traditional fisheries gears to sample the fish communities in lakes 100 – 10,000 acres (40–4,050 hectares) between mid-June and early-September. In each surveyed lake, double frame 19 mm mesh trap nets and standard graduated mesh gill nets (i.e., five 15.2 m long x 1.8 m deep panels of 19 mm, 25 mm, 32 mm, 38 mm, and 51 mm bar mesh) are used to sample littoral and limnetic areas, respectively (MNDNR 2017). All fish are identified to species, measured to the nearest mm, and a subset are weighed to the nearest gram. A combination of seines (i.e., 15.2 and 4.6 m long x 1.5 m deep with 3 mm bar mesh) and backpack electrofishers are used to sample nearshore, wadeable areas of each lake along 30.5 m stations. There are sampling protocols to address difficult to sample shorelines (e.g., boat assisted seining along steep shorelines and boat assisted backpack electrofishing among or along stands of aquatic vegetation) to ensure sufficient sampling effort in a wide variety of lakes. All fish captured in nearshore gears are identified to species and enumerated, and a subset of specimens from each species are vouchered and independently verified in a lab setting.

The numbers of gill nets and trap nets set and number of nearshore sampled followed MNDNR lake survey methods (MNDNR 2017) and are determined by the size and characteristics of the lake. Typically, trap nets are set in 9–15 locations, gill nets in 6–15 locations, and sampling with nearshore gears is completed at 10–24 locations. Net sites were chosen in historic surveys systematically to represent available habitat within each lake. Nearshore sampling stations were equally spaced around the shoreline of the lake from a random starting point. See MNDNR (2017) for further details.

2. Assessment data and methods

FIBI survey data is collected prior to assessment, typically within a six-year window just prior to assessment. For each lake, typically one or two surveys are completed within the six-year window, but occasionally more are completed when time permits, when results are ambiguous, or when randomly selected as a repeat survey (conducted on at least 10% of lakes annually). Only FIBI surveys meeting minimum sampling requirements and collected within the summer survey season (mid-June to early September) are included as primary assessable information. Older survey data or survey data collected with non-standard effort or timing is considered as supporting information to the assessment.

Multiple scores are often considered when making an assessment on an individual lake. However, if FIBI scores are similar among surveys conducted within seasons and between years relative to the range of scores observed (Bacigalupi et al. 2021), data from just one or two survey events may be used in most cases for determining lake condition and making a biological assessment decision. When FIBI scores are disparate or fall close to a threshold (within the 90% Confidence Interval), an effort is made to collect additional survey data before an assessment determination. The FIBI survey data and assessment recommendations are reviewed first by a panel of MNDNR experts, and later by MPCA biological, water quality, and watershed experts to make a final assessment determination. In addition to FIBI scores, other factors are considered such as survey effort or timing, natural condition, or the influence of connected lakes. Lakes that are recommended to be listed as impaired by MPCA and MNDNR staff are then reviewed by local and regional water resource staff. The list of impaired waters are presented at public meetings, then open to public review and comment, and finally submitted to the United States Environmental Protection Agency (EPA) for approval. See MPCA (2021) and https://www.pca.state.mn.us/water/defining-impaired-waters for more details on the assessment and impaired waters listing process.

FIBI scores and supporting information are used to place lakes into one of the following assessment categories: fully supporting (FS), not supporting (impaired) (NS), inconclusive information (IC), insufficient information (IF), or not assessable (NA). Generally, if the FIBI scores fall above the General Use impairment threshold, a lake is assessed as fully supporting (FS) the aquatic life use. If scores fall below the General Use impairment threshold, a lake is assessed as not supporting (NS) the aquatic life use. When repeated surveys fall on either side of an impairment threshold, the lake is typically assessed as having inconclusive information (IC). When data is old or survey collection is incomplete, a lake is assessed as having insufficient information (IF). Lakes that are currently FS or IC can also be given a subcategory of vulnerable (V) indicating that scores are near the impairment threshold and stressors are present in the lake, suggesting the lake may become impaired if protective or restoration actions are not initiated. Lakes that are fully supporting with an exceptionally high score are identified (FS-E). Rarely, a lake is classified as not assessable (NA) when a lake is unrepresentative of lakes used during FIBI development (e.g., smaller than 100 acres (40 hectares) or routinely affected by severe winterkill).

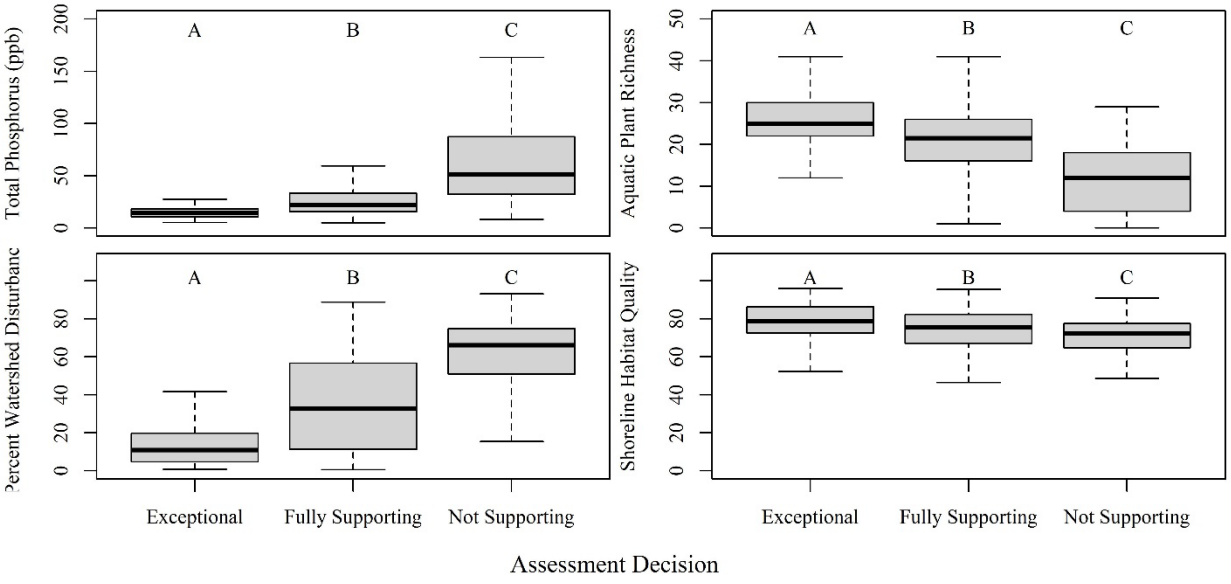
In addition to assessing lakes, DNR staff study stressors affecting the biological communities found in impaired and vulnerable lakes. Numerous stressors are considered during this process, but most often, the focus is on the impacts of water quality and shoreline habitat on the fish community. Stressor identification investigations and reporting (SID) involves evaluation of several of the most likely stressors to fish communities specifically for each impaired or vulnerable lake (MNDNR 2018).

3. Water quality, land use, shoreline condition relationships with assessment decisions

FIBIs were developed to include metrics responsive to stressors impacting lake habitat (Bacigalupi et al. 2021). During FIBI development, stressors considered for metric selection included disturbance within a lake's contributing watershed (i.e., percent agriculture, percent urban, percent forested, and overall percent watershed disturbance as defined in Cross and Jacobson (2013)) as a measure of water quality, sedimentation, hypolimnetic oxygen availability, and regime shifts. Aquatic plant richness and Floristic Quality Index (FQI) were considered measures of structural fish habitat, and dock density (Beck et al. 2013) was used as a measure of shoreline disturbance and recreational pressure. For lakes used during development of each of the FIBIs, scores were negatively correlated with percent watershed disturbance and positively correlated with FQI. Scores were also negatively correlated with dock density; however, these correlations were not statistically significant (Bacigalupi et al. 2021). Since implementation of

assessments, most FIBI impairments using the General Use impairment threshold are in lakes with watershed disturbance occurring in more than half of the upstream catchment and lakes with high levels of total phosphorus (TP). Meanwhile, most lakes that have been identified as containing exceptional fish communities are located in predominantly forested watersheds, with higher aquatic plant species richness, lower TP levels, and higher quality shorelines (Figure 5). These results demonstrate that the FIBIs, biocriteria, and assessment are appropriate and capable of accurately identifying lakes in need of restoration or protection.

Figure 5. Relationships between four variables representative of aquatic habitat stressors and aquatic life use assessments, including Exceptional Use, fully supporting, and not supporting determinations based on FIBI scores. Total phosphorus is calculated as the 10-year average of measurements obtained from MPCA and updated annually. Aquatic plant richness is summarized from MNDNR aquatic plant survey data. 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. Land use categories are described in Jin et al. (2019). Calculations of watershed disturbance from Watershed Health Assessment Framework (MNDNR 2021). Shoreline habitat quality is measured by Score the Shore scores (Perleberg et al. 2019) which assess the integrity of lakeshore habitat. Letters above boxplots denote significant differences between determination categories.



4. Exceptional Use Determination

Currently, lakes identified as having exceptionally high scores do not have strict data requirements as the category has been informal and is used primarily for prioritization. However, determination of Exceptional Use as an official assessment category and consequently a higher impairment threshold, based on the FIBI will include strict data requirements as well as professional review.

Survey data must be collected per the FIBI methodology described in the previous sections. In addition, a lake must meet one or more of the following criteria:

1. One FIBI score at least 10 points above the proposed Exceptional Use threshold (see Figure 8), or
2. Two or more surveys with scores above the Exceptional Use threshold. The surveys must be in different years and use separate trap net and nearshore data.

In addition, a professional review by MNDNR will be completed to consider supporting information such as older surveys, FQI, data on other biological communities (LOBS), and data on stressors impacting the

lake (such as water chemistry data, shoreline disturbance, watershed disturbance). If any scores within the previous 10 years fall below the Exceptional Use threshold, in most cases, the lake will not be classified as Exceptional Use. Exceptions may include if a lower scoring survey had non-standard or low effort, if water temperatures during sampling were lower than 21°C surface temperature, or if there were other quality assurance/quality control concerns.

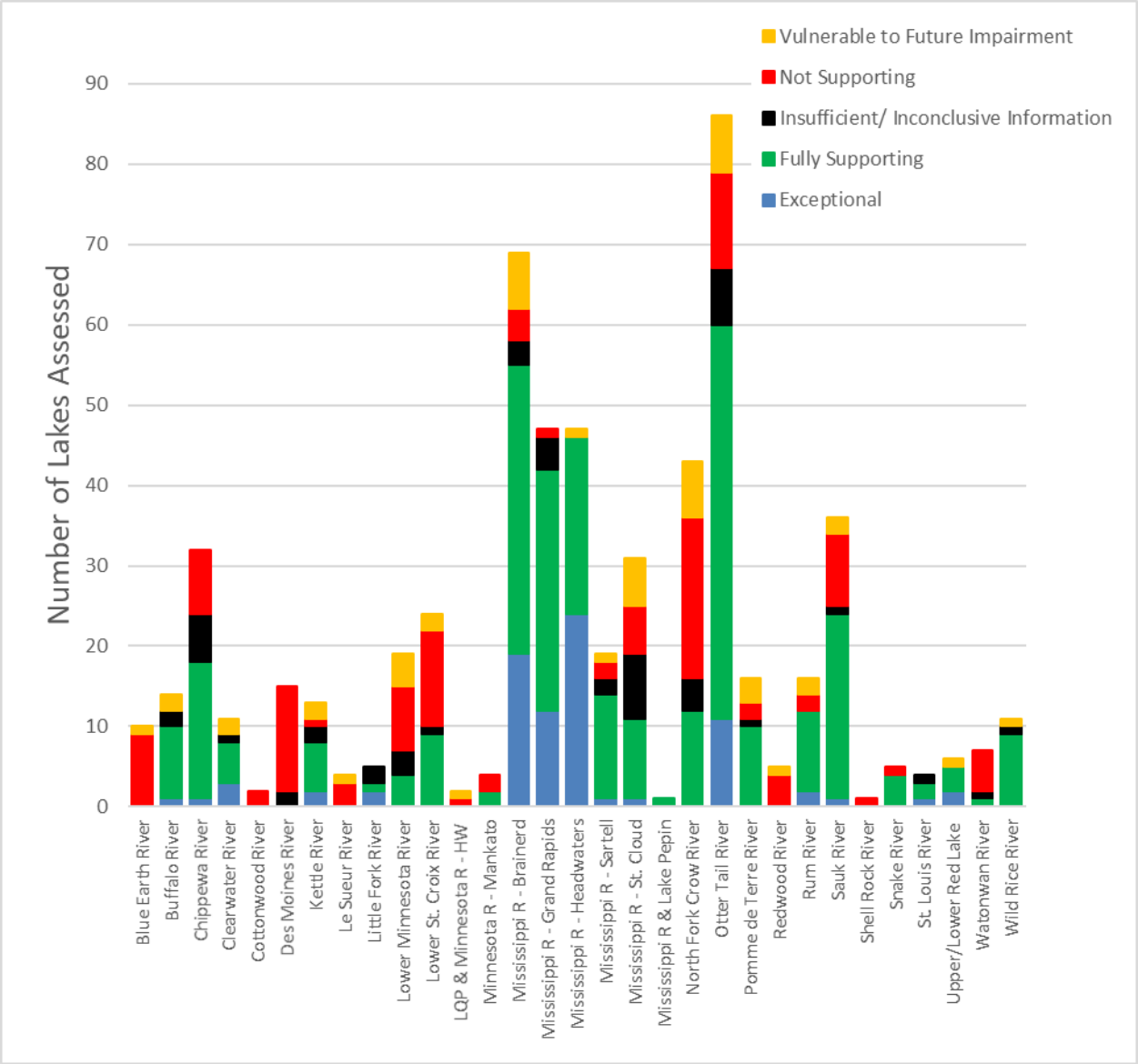
If a lake is classified as Exceptional Use, and then in a subsequent assessment scores below the Exceptional Use threshold, the lake will be designated as impaired and stressor identification be completed. Similarly, an Exceptional Use lake could be designated as vulnerable to future impairment and suggested as a priority for protection and/or restoration actions. A lake that was formerly designated as General Use can be changed to Exceptional Use if there is survey data and supporting information to support the designation change.

5. Examples

Between 2015 and 2021, MNDNR completed biological assessments in 605 lakes in 33 watersheds (Figure 6), and although additional assessments have since been completed, the information available at that time was used for the examples discussed in this section. MNDNR and MPCA biologists used the data during that period to determine that 21% of those lakes were not supporting the aquatic life use (i.e., not meeting standards). Another 9% of lakes were identified as vulnerable to future impairment based on fish IBI scores near the impairment threshold coupled with evidence of stressors in the watershed and/or in the shoreline zone. The MNDNR is also maintaining a list of lakes with exceptionally high FIBI scores which includes 14% of lakes assessed through 2021.

Existing General Use impairment biocriteria allow for a loss of some species and moderate changes in community structure before an impairment is identified. However, many Minnesota lakes, particularly in the northern, forested area of the state, support high biodiversity, and are nearly always associated with high quality habitat required to support fish species intolerant of disturbance. Some of the species sampled are species of greatest conservation need in Minnesota (e.g., Lake Sturgeon, Least Darter, Northern Longear Sunfish, and Pugnose Shiner). Numerous lakes currently have exceptional fish communities and would benefit from a TALU approach.

Figure 6. The number of lakes assessed and determinations for watersheds assessed 2015 - 2021.



a. Example 1: Pilot assessments for Exceptional Use determination

Part of the process of evaluating the draft Exceptional Use tier and biocriteria included an assessment exercise for lakes that would be potential candidates for an Exceptional Use assignment. The exercise included evaluating all lakes that had at least one recent survey (2010 – 2019) and one or more scores above the Exceptional Use threshold (314 surveys on 182 lakes). The 182 lakes were located primarily in northern Minnesota, in 14 MNDNR Fisheries Management Areas (FMAs; Figure 7).

The 182 lakes were put into three categories for evaluation:

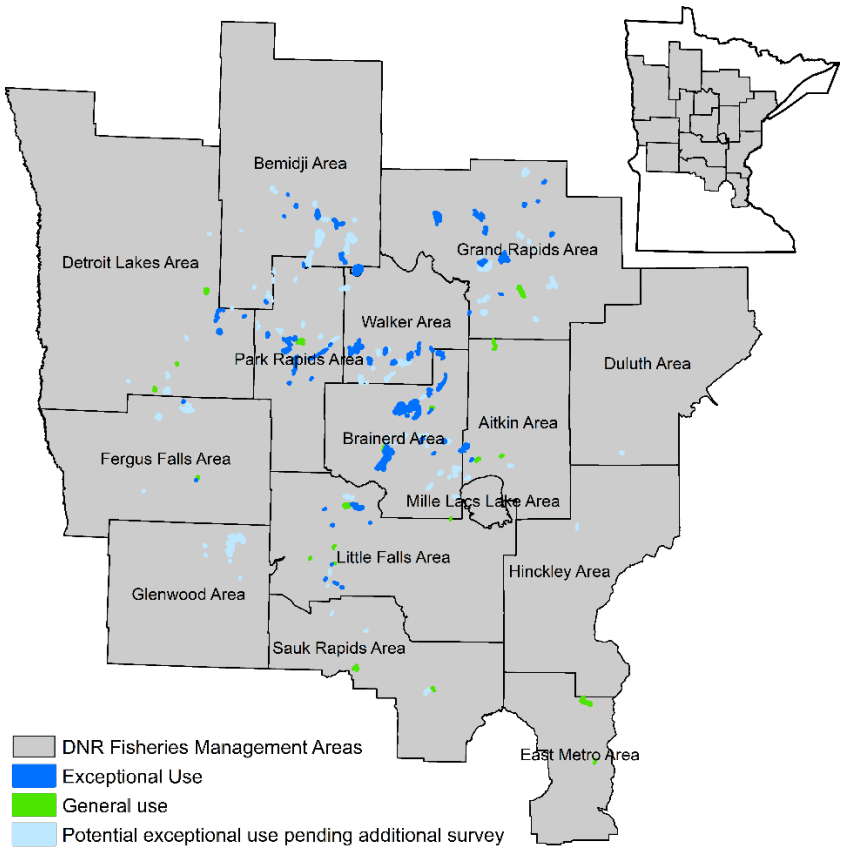
- Exceptional Use (77 lakes):
  - Either: 1) one FIBI score at least 10 points above the proposed exceptional threshold, or 2) two or more surveys with scores above the Exceptional Use threshold.

- And, no recent scores (since 20133) below the Exceptional Use threshold unless there were mitigating circumstances (low effort or non-standard effort, low water temperatures noted, other).

- Potential Exceptional Use, pending an additional survey (for actual assessments, we would complete an additional survey to make this determination) (86 lakes): One FIBI score above Exceptional Use threshold, but less than 10 points above.
- General Use (19 lakes): Recent, full effort FIBI scores mixed, above and below the Exceptional Use threshold or older FIBI score(s) above, but more recent score(s) below.

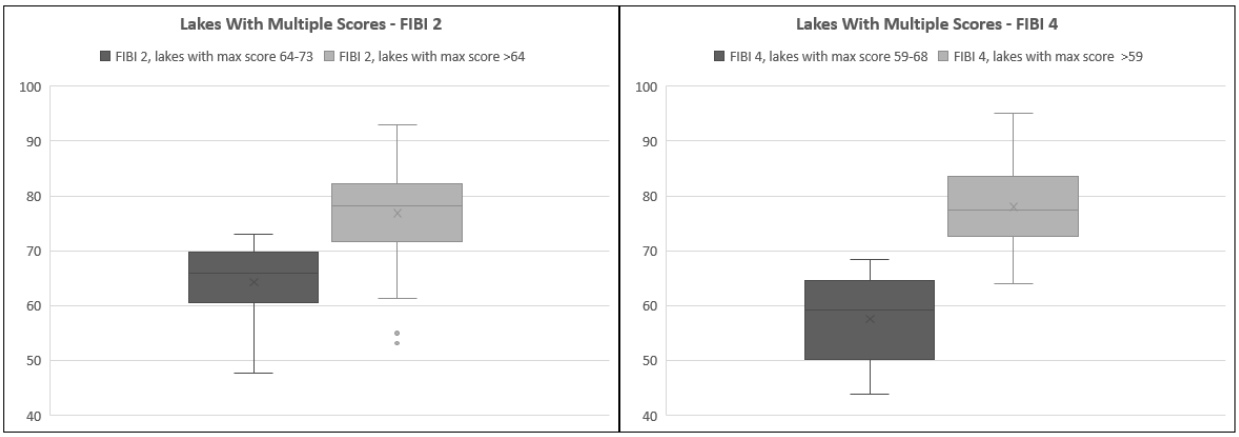
Two or more surveys are always preferred, but in some cases, are logistically difficult. Ten points above the threshold was used as a cut-off for making a determination for lakes with just one survey because no FIBI 4 lakes and only three FIBI 2 lakes that had one score 10 points or more above the Exceptional Use threshold also had a recent survey scoring below the Exceptional Use threshold (Figure 8). In addition, 10 points is stricter than the 90% confidence interval for each FIBI (see Figure 4).

Figure 7. Map showing the locations of lakes with one or more surveys above the Exceptional Use threshold. Exceptional Use (dark blue) indicates lakes with multiple surveys above the threshold or one survey 10 or more points above the threshold. Potential (light blue) indicates lakes with scores less than 10 points above the threshold. General Use (green) indicates lakes with scores from multiple surveys both above and below the threshold.



[3] No FIBI protocol changes have occurred since 2013 so data collected after this date are less likely to be affected by methodological changes versus actual changes in fish community condition.

Figure 8. Range of FIBI scores for lakes with multiple surveys, including one or more Exceptional Use FIBI score. The dark gray boxes show the range, median, and average scores for lakes with the maximum score less than 10 Points above the respective Exceptional Use threshold. The light gray boxes show the range, median, and average scores for lakes with the maximum score 10 or more points above the respective exceptional threshold.



FMA Supervisors or their delegates were asked to use their professional judgement to evaluate the Exceptional Use biocriteria and comment on if the Exceptional Use designation seemed appropriate for each lake. For each lake, FIBI scores, survey notes, and stressor information were provided to the FMA Supervisor. The results of the Area review of each lake are summarized in Table 3. In 86% of the lakes, the FMA review agreed with the pilot use determination based on their local knowledge of the fish community and lake habitat. The FMA disagreed with 12% of the pilot assessment recommendations and the FMA did not have enough knowledge of the lake or gave no response for 3% of the lakes. Overall, FMA Supervisors indicated that the Exceptional Use biocriteria seemed appropriate and lined up very well with their knowledge of the fish community diversity and habitat quality. They expressed overwhelming support for adding additional recognition and protection for the highest quality lakes. Several noted that many of the Exceptional Use lakes were well connected to large chains of lakes or rivers, and that many of the Exceptional Use lakes were connected to one another. For these well-connected lakes, several FMA Supervisors indicated a preference to consider the connections in making a determination for General or Exceptional uses.

Table 3. Summary of FMA review and response to pilot assessment, including 182 lakes with one or more surveys with scores above an Exceptional Use threshold.

Pilot assessment category	Fisheries management area review and response	Number of lakes (%)
Exceptional Use	Agree; good Exceptional Use candidate.	69 (38%)
Exceptional Use	Disagree; Area office biologists do not consider the lake a reasonable candidate for Exceptional Use due to high levels of shoreline and/or watershed disturbance or water quality problems that adversely impact fish habitat.	8 (4%)
Potential Exceptional Use pending an additional survey	Agree; good Exceptional Use candidate.	72 (40%)
Potential Exceptional Use pending an additional survey	Disagree; Area office biologists does not consider a reasonable candidate for Exceptional Use due to high levels of shoreline and/or watershed disturbance or water quality problems that adversely impact fish habitat.	8 (4%)
Potential Exceptional Use pending an additional survey	No response from Area office biologists or Area office biologists do not have enough information about the lake.	5 (3%)
General Use standards	Agree; hold to the General Use.	15 (8%)
General Use standards	Disagree; Area office biologists believe lake should be a candidate for Exceptional Use based on its habitat and fish community.	5 (3%)
Total number of lakes Reviewed		182

b. Example 2: Application of TALU in watershed assessments: Crow Wing River, Big Fork River, and Mississippi River Twin Cities watersheds

Three watersheds with numerous lakes that were assessed in 2022 and 2023 are presented as case examples for this report. Note that for several lakes in each watershed, additional survey data was collected after this exercise was completed. Final use classification and assessment recommendations were made after this exercise was completed during assessment for each watershed using professional review of the most up to date FIBI survey data and other supporting information. Final Exceptional Use designations, which were completed after this exercise had been completed, are included in Appendix A. The three watersheds presented in this exercise include: a watershed with numerous potential Exceptional Use lakes that are likely at high risk of degradation due to increasing human disturbance within the watershed, a watershed with little human disturbance and numerous potential Exceptional Use lakes, and a watershed with high human disturbance including areas of intense urban development with numerous lakes scoring below the General Use impairment threshold.

Crow Wing River Watershed (07010106)

The FIBI was used to assess 69 lakes in the Crow Wing River Watershed during winter/spring of 2022. FIBI survey data has been collected in the watershed since 1999; however, only the most recent survey data was used as primary assessment information (2016 – 2021). On lakes with recent data, older FIBI survey data was used as supporting information.

Through 2020 (prior to assessment but for consideration during this exercise), 114 FIBI surveys were completed on 66 Lakes (77 surveys were primary information and 37 were older surveys used as supporting information). An additional 17 surveys were planned for 2021. Sixty-three lakes had recent data (2016 – 2020), of which 12 lakes had additional surveys planned in 2021. Three lakes had older data (2003 – 2012) with surveys planned in 2021 and three lakes were scheduled for their first FIBI survey in 2021.

The Crow Wing River Watershed is primarily forested land (41%) and wetland (23%), but there is substantial land use classified as developed (4%), cultivated (10%), or pasture/hay (10%) (MNDNR (2021); based on National Land Cover Database (NLCD) land cover classifications described in Homer et al. (2012)). Despite increasing agricultural, residential, and other development in the watershed, the watershed still contains numerous high quality natural resources, with 38% of lakes sampled through 2020 having at least one score above the Exceptional Use threshold. Several of the potential Exceptional Use lakes in the Crow Wing River Watershed are connected, which likely leads to higher habitat and fish species diversity. Given the increasing watershed development, the Crow Wing River watershed is a good example of a watershed where there is urgency to implement protection for exceptional lakes. Of the 66 lakes with data, 20% had an FIBI score 10 or more points above the Exceptional Use threshold, and an additional 18% of lakes had one score above the Exceptional Use threshold, with an additional FIBI survey planned in 2021 (Figure 9). Some of the lakes with a FIBI surveys completed in 2021 and/or 2022 were added to the final list found in Appendix A.

Two Lakes (Bad Medicine (03008500) and Bass (03012700)) had multiple recent surveys with scores above and below the General Use impairment threshold and are likely vulnerable for future impairment. An additional lake (Sibley (18040400)) survey had one FIBI score near the impairment threshold and was scheduled for an additional survey in 2021. These lakes should be prioritized for protection and restoration actions to prevent them from becoming impaired. One lake, West Crooked (29010103), had multiple recent FIBI scores below the General Use impairment threshold indicating nonattainment of aquatic life use goals.

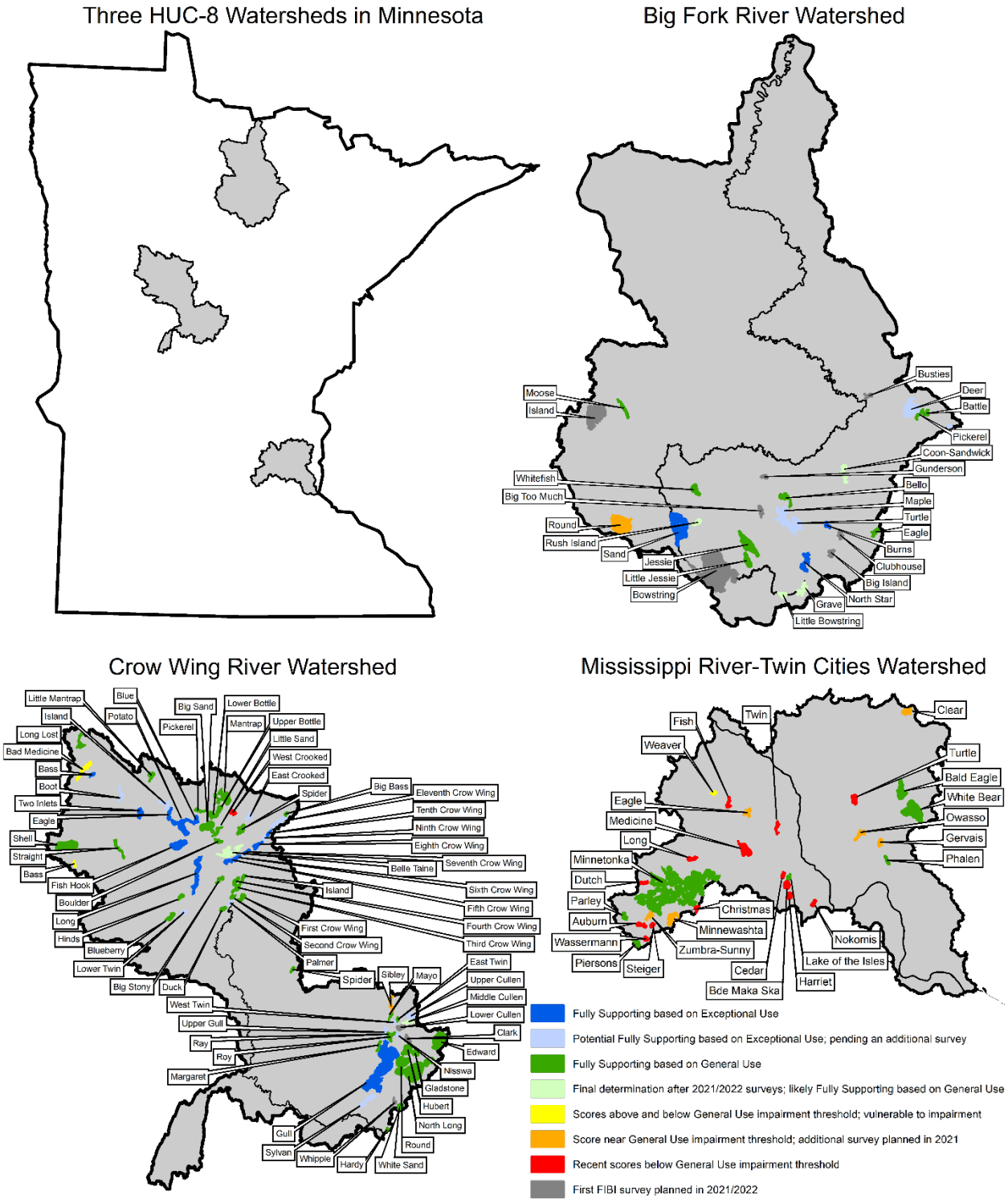
Big Fork River Watershed (09030006)

The FIBI was used to assess 27 lakes in the Big Fork River Watershed during winter/spring of 2023. FIBI survey data has been collected in the watershed since 2005, however only the most recent survey data was used as primary assessment information (2016 – 2022). On lakes with recent data, older FIBI survey data was used as supporting information.

Through 2020 (prior to assessment but for consideration during this exercise), 27 FIBI surveys were completed on 20 lakes (15 surveys were primary information and 12 were older surveys used as supporting information). An additional 16 surveys were planned in 2021 and 2022. Fifteen lakes had recent data (2016 – 2020). Five lakes had older data (2005 – 2012) with surveys planned in 2021 or 2022 and seven lakes were scheduled for their first FIBI survey in 2021 or 2022.

The Big Fork River Watershed is primarily wetland (64%) and forested land (26%) with less than 3% of the land cover classified as developed or agricultural (MNDNR 2021; based on NLCD land cover classifications described in Homer et al. (2012)). As such, the watershed contains numerous high quality natural resources and is a good example of a relatively pristine watershed that will benefit from implementation of a TALU framework to ensure protection of exceptional resources into the future. Of the 20 lakes with data, 35% had scores above the Exceptional Use threshold (Figure 9). Some of the seven lakes with FIBI surveys completed in 2021 or 2022 were added to the final list in Appendix A. One lake, Round (31089600) had one recent FIBI score near the General Use impairment threshold; an additional survey was planned in 2021 to determine the FIBI assessment recommendation.

Figure 9. Example of application of TALU in three upcoming watershed assessments: Crow Wing River, Big Fork River, and Mississippi River Twin Cities watersheds.



Mississippi River - Twin Cities Watershed (07010206)

The FIBI was used to assess 30 Lakes in the Mississippi River - Twin Cities Watershed during winter/spring of 2022. FIBI survey data has been collected in the watershed since 1998, however only the most recent survey data was used as primary assessment information (2016 – 2021). On lakes with recent data, older FIBI survey data was used as supporting information.

Through 2020 (prior to assessment but for consideration during this exercise), 75 FIBI surveys were completed on 30 lakes (30 surveys were primary information and 45 were older surveys used as supporting information). An additional six surveys were planned in 2021. Twenty-seven lakes had recent data (2016 – 2020), of which three lakes had additional surveys planned in 2021. Three lakes had older data (1999 – 2011) with surveys planned in 2021.

The Mississippi River - Twin Cities Watershed is primarily developed land use (54%), and also includes substantial amounts of cultivated (8%) and pasture/hay land (9%) (MNDNR 2021; based on NLCD land cover classifications described in Homer et al. (2012)). In the Mississippi River drainage, the FIBI scores generally decrease and watershed disturbance increases, from the headwaters to the lower portions of the drainage (Figure 6). Most of the drainage has the same biogeographic pool of species and therefore it is likely that the primary driver of lower FIBI scores is human disturbance. The Mississippi River Headwaters, Mississippi River – Grand Rapids, and Mississippi River – Brainerd watersheds all have numerous lakes scoring above the Exceptional Use thresholds (26-51% of assessed lakes), and few impairments. In the Mississippi River – Sartell, most lakes were fully supporting based on the General Use threshold with a few lakes vulnerable to impairment or impaired based on the FIBI, with 1 lake scoring above the exceptional threshold. Similarly, one lake had a score above the Exceptional Use threshold in the Mississippi River – St. Cloud watershed and 39% of lakes were determined to be impaired or vulnerable to impairment based on the General Use threshold.

In the Mississippi River - Twin Cities Watershed, a large proportion of the lakes were likely to be listed as impaired based on the FIBI General Use threshold. No lakes in the watershed were likely to be proposed as Exceptional Use. Of the 30 lakes with data, one lake (White Bear Lake (82016700)), had one score equal to the Exceptional Use threshold, but additional surveys scores were well below the Exceptional Use threshold. Based on data through 2020, 30% of lakes had FIBI scores above the General Use threshold, 47% of lakes had scores below the General Use threshold, and one lake (Weaver (27011700)) had scores on each side of the threshold and was likely vulnerable to future impairment. Additional surveys were planned on 6 lakes, all with older or recent scores very near the General Use impairment threshold (Figure 9).

c. Assessment summary

Examples 1 and 2 demonstrate the need for and reasonableness of a TALU framework for lakes. Within many watersheds there are many lakes that currently meet Exceptional Use thresholds especially lakes with abundant natural shoreline habitat and good water quality in the northern forested portions of the state that would benefit from a TALU framework and implementation of an Exceptional Use threshold. In addition, in central Minnesota watersheds, a smaller number of lakes remain that meet the Exceptional Use threshold and that should be prioritized for protection in landscapes experiencing land use changes and other stressors. The General Use biocriteria are suitable to protect or restore lakes in areas with greater disturbance and where the Exceptional Use is not an existing use.

In addition, Example 1 demonstrates that the proposed thresholds are appropriate. The results of the pilot assessment match expectations of Fisheries Area staff who have decades of experience and correspond with watershed disturbance and other stressors. By requiring a second survey or a score

above the 90% Confidence limit and professional review, we can be confident that lakes determined as Exceptional Use are appropriate.

E. Use designation reviews

The MPCA routinely reviews use designations to ensure that beneficial uses assigned to streams, lakes, and wetlands are protective and attainable as defined by the CWA and Minnesota Rule. As a result of routine monitoring, the MPCA and MNDNR have identified lakes where the currently designated beneficial use does not accurately reflect an attainable use. The most important reason to assign accurate beneficial uses to these water bodies is that the designated use for each water affects many of the water quality protection and restoration efforts at the MPCA (e.g., assessment, stressor identification, National Pollutant Discharge Elimination System [NPDES] permitting, Total Maximum Daily Loads [TMDLs]). Fundamentally, assigning the correct beneficial uses to Minnesota's waters also serves to accurately document the types and condition of Minnesota's aquatic resources.

The draft use designations in this document only affect Class 2 (i.e., aquatic life and recreation) and are focused on aquatic life beneficial uses. The amendments to Minn. R. 7050.0470 described herein serve as the technical documentation for these designations. This section includes a list of lakes proposed to be designated, and Appendix A includes a technical justification for each use designation. This information is provided as part of the adoption of the TALU framework for lakes to demonstrate the process for documenting and proposing TALUs under this framework.

The use designations proposed in this document are the result of routine use reviews that are performed as part of MPCA's IWM efforts. All reviews in this document are TALU reviews in watersheds that were monitored in 2020-2022 (and subsequently assessed in 2022-2024). In addition, many warm water (Class 2B) lakes have been identified in the "Development of water quality standards to protect coldwater lake habitats in Minnesota" (MPCA 2025) that will be designated as cold water (Class 2A) for the protection of coldwater habitat for Lake Trout, Lake Whitefish, Cisco, or stream trout. These coldwater reviews are part of a separate, statewide effort to review and document the status of coldwater fish populations in Minnesota.

In total, the draft use designations in this document include TALU designations for 36 lakes (Tables 4 and 5). In Table 5 and throughout the remainder of this document, use designations are organized hierarchically by major watershed and then by HUC 8. Within HUCs, water bodies are sorted by division of waters (DOW) number. Following the use designation table, there is a description of the use designation process. In Appendix A, are descriptions of the evidence supporting the draft use designation for each water body.

Table 4. Summary of use designation proposals for lakes.

Current use	Proposed use	# of DOWs
2B	2Be	9
2B	2Ae[TLC]	25
2B	2Ae[LKW,TLC]	1
2A[SRT]	2Ae[TLC,SRT]	1

Table 5. List of draft use designations (abbreviations: DOW = division of waters lake number, 2B = general cool and warm water aquatic life and habitat; 2Be = exceptional cool and warm water aquatic life and habitat, 2A = general cold water aquatic life and habitat, 2Ae = exceptional cold water aquatic life and habitat, TLC = Cisco coldwater habitat, LKW = Lake Whitefish coldwater habitat, SRT = stream trout coldwater habitat, TALU = tiered aquatic life use review).

DOW	Lake name	Current use class	Draft use class	Acres	County	Use review type
Minn. R. 7050.0470, subp. 2. Lake of the Woods Basin						
2.B.(5) Big Fork River Watershed (09030006)						
31016000	Mirror	2B	2Be	109.11	Itasca	TALU
31054000	Clubhouse	2B	2Ae[TLC]	265.3	Itasca	TALU
31062400	Grave	2B	2Ae[TLC]	524.65	Itasca	TALU
31065300	North Star	2B	2Ae[TLC]	831.63	Itasca	TALU
31065400	Burns	2B	2Be	181.29	Itasca	TALU
31072500	Turtle	2B	2Ae[LKW,TLC]	2125.63	Itasca	TALU
31079300	Big Too Much	2B	2Ae[TLC]	291.96	Itasca	TALU
Minn. R. 7050.0470, subp. 4. Upper Mississippi River Basin						
4.B.(6) Crow Wing River Watershed (07010106)						
03001700	Two Inlets	2B	2Ae[TLC]	577.98	Becker	TALU
03003000	Boot	2B	2Ae[TLC]	385.1	Becker	TALU
11030400[4]	Sylvan	2B	2Be	894.03	Cass	TALU
11030500	Gull	2B	2Ae[TLC]	10010.01	Cass	TALU
18037600	Upper Cullen	2B	2Ae[TLC]	434.56	Crow Wing	TALU
18037700	Middle Cullen	2B	2Ae[TLC]	396.65	Crow Wing	TALU
18040900	West Twin	2B	2Be	127.49	Crow Wing	TALU
29002500	Ninth Crow Wing	2B	2Ae[TLC]	232.4	Hubbard	TALU
29003600[5]	Eleventh Crow Wing	2B	2Ae[TLC]	750.97	Hubbard	TALU
29004500	Tenth Crow Wing	2B	2Ae[TLC]	175.21	Hubbard	TALU
29007200	Eighth Crow Wing	2B	2Be	502.97	Hubbard	TALU
29008700	Palmer	2B	2Be	146.25	Hubbard	TALU
29009100	Seventh Crow Wing	2B	2Ae[TLC]	262.4	Hubbard	TALU
29009200	Fifth Crow Wing	2B	2Ae[TLC]	400.12	Hubbard	TALU
29009300	Sixth Crow Wing	2B	2Ae[TLC]	345.63	Hubbard	TALU
29016100	Long	2B	2Ae[TLC]	1926.11	Hubbard	TALU
29018400	Blue	2A[SRT]	2Ae[TLC,SRT]	336.35	Hubbard	TALU
29024200	Fish Hook	2B	2Ae[TLC]	1642.57	Hubbard	TALU
29024300	Potato	2B	2Ae[TLC]	2096.1	Hubbard	TALU

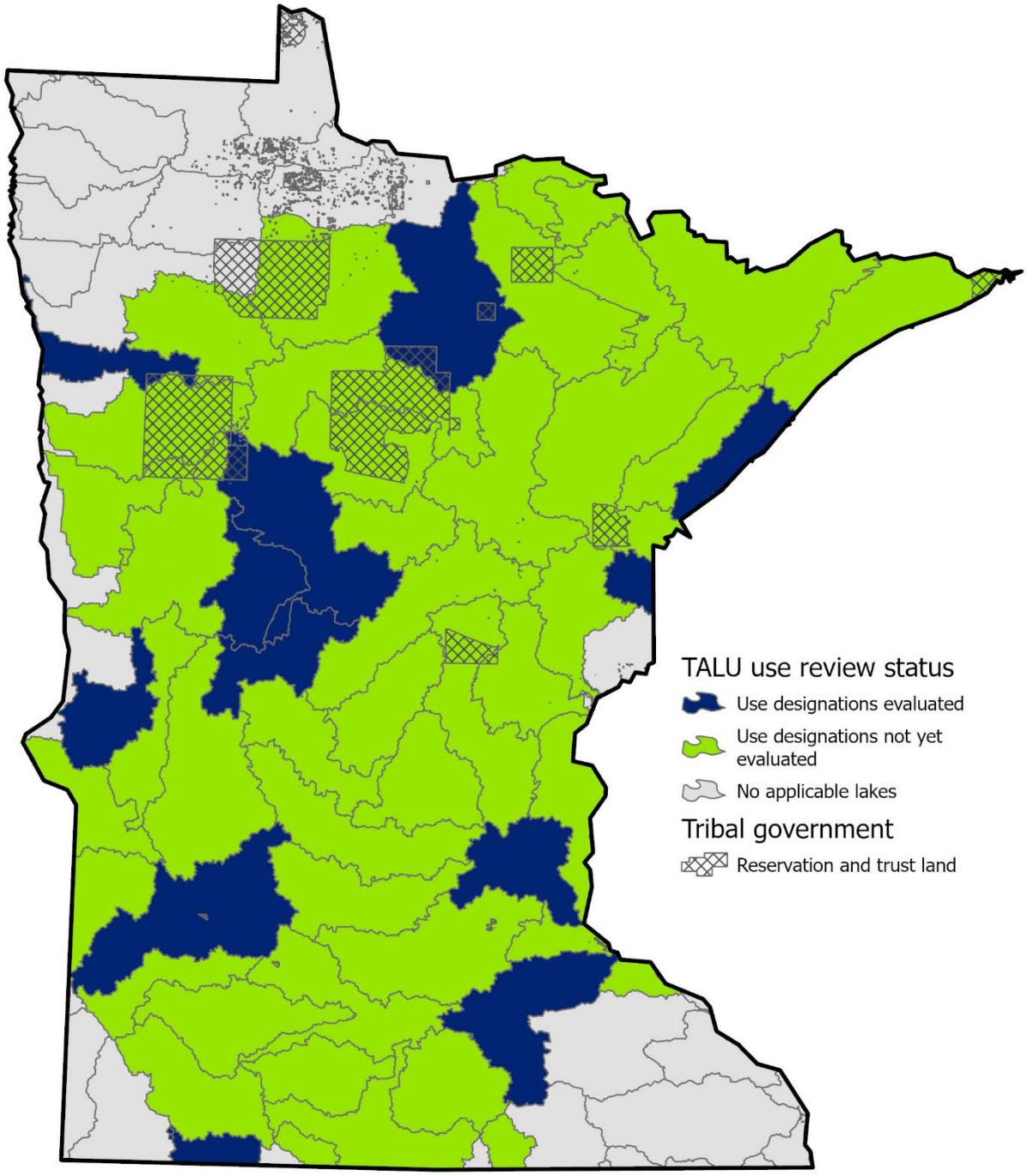
[4] Includes both basins: 11-0304-01 and 11-0304-02.
[5] Includes both basins: 29-0036-01 and 29-0036-02.

DOW	Lake name	Current use class	Draft use class	Acres	County	Use review type
29025400	Island	2B	2Ae[TLC]	541.25	Hubbard	TALU
29025600	Eagle	2B	2Ae[TLC]	423.53	Hubbard	TALU
80003000	Lower Twin	2B	2Be	251.91	Wadena	TALU
4.B.(8) Long Prairie River Watershed (07010108)						
21008300	Miltona	2B	2Ae[TLC]	5731.02	Douglas	TALU
21010800	Mina	2B	2Ae[TLC]	411.42	Douglas	TALU
21012300	Ida	2B	2Ae[TLC]	4445.3	Douglas	TALU
49007900	Alexander	2B	2Ae[TLC]	2708.78	Morrison	TALU
49012700	Shamineau	2B	2Be	1434.02	Morrison	TALU
49013300	Crookneck	2B	2Be	183.06	Morrison	TALU
77012000	Charlotte	2B	2Ae[TLC]	144.32	Todd	TALU

The TALU designations in this document are the result of routine monitoring during the 2020-2022 IWM efforts (Figure 10). Determination of the proposed uses were made through a review to determine the attainable aquatic life use goal for each lake. Use designation reviews begin with a review of biological condition. If the fish assemblage meets the Exceptional Use biocriteria, then the reach is eligible for designation as Exceptional Use (Figure 3 and Table 1), with habitat and stressor information considered secondarily and used as supporting evidence. If the fish assemblage does not meet the Exceptional Use criteria, the lake will be confirmed General Use. General Use is the default designation when sufficient data are unavailable for a review. Furthermore, General Use is the confirmed designation when sufficient data are available, and a lake is determined not to meet the Exceptional Use. The TALU framework for lakes differs from streams in that there is no Modified Use for lakes.

For each TALU designation, supporting evidence for the draft use designation is documented in Appendix A of this document. In addition to providing a narrative description of the TALU use designation reviews, detailed biological, habitat, and stressor information is tabulated.

Figure 10. Map of TALU use designation review status by watershed.



F. Rule language changes

To adopt a TALU framework for lakes, several revisions to Minn. R. 7050 will be required. To describe the TALUs for lakes, language will need to be added to incorporate lakes into the existing narratives for each TALU tier under Classes 2A, 2Bd, and 2B in Minn. R. 7050.0222, subps. 2c, 3c, and 4c. In addition, lake-specific references will be added to detail how fish community condition is measured and how the biological criteria were developed for lakes. Amendments to Minn. R. 7050.0222, subps. 2d, 3d, and 4d will also add biological criteria for Classes 2A, 2Bd, and 2B, as well as for each lake type and TALU. These revisions will reasonably describe the expectations for each TALU, provide documentation to justify each use, and provide transparency and consistency regarding the MPCA's process of assessing aquatic life use goals for lakes. In addition to incorporating a TALU framework for lakes into rule, Exceptional Use designations will be adopted for 36 lakes into Minn. R. 7050.0470. Adoption of these use designations into rule will provide clarity regarding the aquatic life goals for these lakes and their inclusion in this rule also serves to demonstrate the process for adopting new Exceptional Uses for lakes into rule.

G. Summary

Minnesota's TALU framework will adopt two aquatic life use tiers into rule under Class 2: General Use and Exceptional Use. Biological criteria for these two tiers will be adopted into rule along with supporting documentation incorporated by reference into rule. There is extensive experience implementing these fish monitoring and assessment tools as part of a CWA program which demonstrate their feasibility and the benefit of using fish as indicators of beneficial use attainment in Minnesota lakes. The methods have been both tested through implementation as a numeric translator for narrative standards (i.e., General Use) and through a pilot designation and assessment exercise (i.e., Exceptional Use). These efforts have demonstrated that the implementation of a TALU framework for lakes is reasonable and is supported by water quality programs in Minnesota. Adding the Exceptional Use tier to Minnesota's lake assessment tools provides additional options for the management of these waters and formally acknowledges the high quality of these lakes. Assigning Exceptional Use goals to lakes which indicate this high quality is an existing use, will provide the benefits of protecting these important and valuable resources. Protecting these lakes is also more cost effective than working to restore them once they have been degraded (Radomski and Carlson 2018). The adoption of a TALU framework for lakes will enhance the ability for the MPCA, MNDNR, local governments, other state agencies, and Tribes to manage Minnesota's lakes to their highest attainable uses which will improve water quality protection and restoration outcomes.

H. References

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

Beck, M.W., B. Vondracek, L.K. Hatch, and J. Vinje, 2013. Semi-automated analysis of high-resolution aerial images to quantify docks in glacial lakes. ISPRS Journal of Photogrammetry and Remote Sensing 81: 60-69.

Bouchard Jr., R.W., S. Niemela, J.A. Genet, C.O. Yoder, J. Sandberg, J.W. Chirhart, M. Feist, B. Lundeen, and D. Helwig, 2016. A novel approach for the development of tiered use biological criteria for rivers and streams in an ecologically diverse landscape. Environmental Monitoring and Assessment 188: 196.

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

Davies, S.P. and S.K. Jackson, 2006. The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16: 1251–1266.

Gerritsen, J., R.W. Bouchard Jr., L. Zheng, E.W. Leppo, and C.O. Yoder, 2017. Calibration of the biological condition gradient in Minnesota streams: a quantitative expert-based decision system. Freshwater Science 36: 427–451.

Gerritsen, J. and J. Stamp, 2014. Biological condition gradient (BCG) models for lake fish communities of Minnesota. Final Report, Tetra Tech, Inc., Owings Mills, MD.

Homer, C.H., J.A. Fry, and C.A. Barnes, 2012. The National Land Cover Database, U.S. Geological Survey Fact Sheet 2012-3020, 4 p. Available: https://pubs.usgs.gov/fs/2012/3020/

Jin, S., C. Homer, L. Yang, P. Danielson, J. Dewitz, C. Li, Z. Zhu, G. Xian, and D. Howard, 2019. Overall methodology design for the United States National Landcover Database 2016 products. Remote Sensing 11(24): 2971.

Karr J.R. 2000. Health, integrity, and biological assessment: The importance of whole things. In: Ecological Integrity: Integrating Environment, Conservation, and Health (eds D. Pimentel, L. Westra & R. F. Noss) pp. 209-226. Island Press, Washington, DC.

MNDNR. 2017. Manual of instructions for lake survey. Special Publication 180, Minnesota Department of Natural Resources, St. Paul, MN.

MNDNR. 2018. Stressors to Biological Communities in Minnesota's Lakes, Minnesota Department of Natural Resources, Brainerd, MN.

MNDNR. 2021. Watershed health assessment framework. MNDNR, St. Paul, Minnesota. Available: http://www.dnr.state.mn.us/whaf/index.html. (May 2021).

MPCA. 2021. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List, 2020 assessment and listing cycle, St. Paul, MN. 74 pp. https://www.pca.state.mn.us/sites/default/files/wq-iw1-04k.pdf

MPCA. 2025. Development of water quality standards to protect coldwater lake habitats in Minnesota. MPCA, Report wq-bsm4-04, St. Paul, MN. Available: https://www.pca.state.mn.us/sites/default/files/wq-bsm4-04.pdf. (January 2025).

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.

Radomski, P., and K. Carlson, 2018. Prioritizing lakes for conservation in lake-rich areas. Lake and Reservoir Management 34(4): 401-416.

Schupp, D. H. 1992. An ecological classification of Minnesota lakes with associated fish communities. Investigational Report 417, Section of Fisheries, Minnesota Department of Natural Resources, St. Paul, Minnesota.

Appendix A. Draft TALU designations

The following documentation of the draft use designations correspond to the list of water bodies in Table 5. The lakes are identified by DOW (i.e., division of waters lake number), which identifies the county where the stream is located, the lake number within that county, and a subbasin (if applicable). At the beginning of each HUC 8 watershed, there is a link to the MPCA webpage for that watershed, which includes available reports and other information.

The abbreviations and symbols used in the use designation descriptions and TALU tables are as follows:

Use designations

2Ag	Aquatic Life and Recreation – General Use Coldwater Aquatic Life and Habitat
2Ae	Aquatic Life and Recreation – Exceptional Use Coldwater Aquatic Life and Habitat
2Be	Aquatic Life and Recreation – Exceptional Use Cool and Warm Water Aquatic Life and Habitat
2Bg	Aquatic Life and Recreation – General Use Cool and Warm Water Aquatic Life and Habitat
[LAT]	Lake Trout
[LKW]	Lake Whitefish
[SRT]	Stream trout spp.
[TLC]	Cisco (Tullibee)

TALU table abbreviations

DOW	Division of Waters number
FIBI	Fish Index of Biological Integrity
FQI	Floristic Quality Index
STS	Score the Shore
*	Indicates supplemental survey data that was collected outside of the IWM schedule and/or prior to 2013, when FIBI methodologies became standardized. These data are given lower consideration.
†	Indicates supplemental survey data that was collected using non-standard effort. These data are given lower consideration.

1. Lake Superior Basin

a. Lake Superior – North Watershed (04010101)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lake-superior-north

Use designations not yet evaluated.

b. Lake Superior – South Watershed (04010102)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lake-superior-south

No draft use designations.

c. St. Louis River Watershed (04010201)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/st-louis-river

Use designations not yet evaluated.

d. Cloquet River Watershed (04010202)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/cloquet-river

Use designations not yet evaluated.

e. Nemadji River Watershed (04010301)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/nemadji-river

No draft use designations.

2. Lake of the Woods Basin

a. Rainy River – Headwaters Watershed (09030001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/rainy-river-headwaters

Use designations not yet evaluated.

b. Vermilion River Watershed (09030002)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/vermilion-river

Use designations not yet evaluated.

c. Rainy River – Rainy Lake Watershed (09030003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/rainy-river-rainy-lake

Use designations not yet evaluated.

d. Little Fork River Watershed (09030005)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/little-fork-river

Use designations not yet evaluated.

e. Big Fork River Watershed (09030006)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/big-fork-river

Table 6. Big Fork River Watershed (09030006) biological and habitat data associated with lakes that will be designated as Class 2Ae or 2Be (abbreviations: DOW=division of waters number, FIBI=fish index of biological integrity, STS=score the shore, FQI=floristic quality index, * indicates supplemental, historic survey data, † indicates supplemental, non-standard effort survey data).

DOW	Lake name	FIBI group	FIBI survey year(s)	FIBI score(s)	% watershed disturbance	STS score(s)	FQI % deviation from threshold
31016000	Mirror	2[6]	2022, 2017	71, 72	3	-	54
31054000	Clubhouse	2	2022, 2021	77, 64	3	-	66
31062400[7]	Grave	2	2023, 2022, 2008*	65, 66, 57	5	88	55
31065300	North Star	2	2019	80	7	-	80
31065400	Burns	2	2020	78	4	-	99
31072500	Turtle	2	2017, 2010*, 2010*	64, 75, 66	4	-	114
31079300	Big Too Much	2	2022, 2021	80, 73	3	-	70

Mirror Lake (31016000): Mirror Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (June 2017), two trap net surveys (July 2022 and July 2017), and two nearshore surveys (July 2022 and July 2017). The FIBI scores of 71 and 72 from the recent surveys were above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Mirror Lake. Approximately 3% of the land use in the upstream watershed is classified as developed (NLCD 2016). The most recent aquatic plant survey, a 2000 survey conducted by the Minnesota Biological Survey (MBS), indicates that the lake supports a relatively diverse aquatic plant community (N=21), resulting in an FQI of 30, which is 54% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Mirror Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

Clubhouse Lake (31054000): Clubhouse Lake will be designated Class 2Ae[TLC] because it demonstrates support a coldwater species (Cisco; see MPCA 2025), and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (June 2021), two trap net surveys (July 2022 and July 2021), and two nearshore surveys (July 2022 and July 2021). The FIBI scores of 77 and 64 from the recent surveys were at or above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Clubhouse Lake. Approximately 3% of the land use in the upstream watershed is classified as developed (NLCD 2016). The most recent aquatic plant survey, a 2001 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=28), resulting in an FQI of 33, which is 66% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Clubhouse Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

[6] Note: few Lake Class 20 lakes were used in FIBI development as they are relatively rare and typically have soft water and low species richness.

[7] The MPCA WID database includes both basins of Grave Lake separately (31-0624-01 and 31-0624-02). Both basins will be assigned Class 2Ae[TLC].

Grave Lake (31062400): Grave Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (August 2021), two trap net surveys (July 2022 and July 2023), and two nearshore surveys (July 2022 and July 2023). An additional survey was completed in June 2008 and is provided as supplemental historic information. The FIBI scores of 66 and 65 from the recent surveys were above the Exceptional Use threshold (64). The FIBI score of 57 from the supplemental historic survey was above the General Use threshold (45) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Grave Lake. Approximately 5% of the land use in the upstream watershed is classified as disturbed, with 3% developed and 2% pasture and hay (NLCD 2016). A Score the Shore survey was completed in 2023 and resulted in a mean score of 88 out of 100, indicating high quality lakeshore habitat. The most recent aquatic plant survey, a 2001 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=26), resulting in an FQI of 30, which is 55% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Grave Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

North Star Lake (31065300): North Star Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (August 2019), a trap net survey (July 2019), and a nearshore survey (July 2019). The FIBI score of 80 from the recent survey was above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for North Star Lake. Approximately 7% of the land use in the upstream watershed is classified as developed (NLCD 2016). The most recent aquatic plant survey, a 2001 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=42), resulting in an FQI of 42, which is 113% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to North Star Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

Burns Lake (31065400): Burns Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (June 2020), a trap net survey (August 2020), and a nearshore survey (August 2020). The FIBI score of 78 from the survey was above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Burns Lake. Approximately 4% of the land use in the upstream watershed is classified as developed (NLCD 2016). The most recent aquatic plant survey, a 2001 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=18), resulting in an FQI of 28, which is 99% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Burns Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

Turtle Lake (31072500): Turtle Lake will be designated Class 2Ae[LKW,TLC] because it demonstrates support for coldwater species (Lake Whitefish and Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (August 2017), a trap net survey (July 2017), and a nearshore survey (July 2017). Two additional surveys were completed in August 2010 and are provided as supplemental historic information. The FIBI score of 64 from the recent survey was at the Exceptional Use threshold (64). The FIBI scores of 75 and 66 from the supplemental historic surveys were above the Exceptional

Use threshold. Select stressor and habitat information was reviewed for Turtle Lake. Approximately 4% of the land use in the upstream watershed is classified as disturbed, with 4% developed and <1% pasture and hay (NLCD 2016). The most recent aquatic plant survey, a 2013 survey conducted by the Lake Ecology Unit indicates that the lake supports a diverse aquatic plant community (N=42), resulting in an FQI of 43, which is 114% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Turtle Lake with the Class 2Ae[LKW,TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

Big Too Much (31079300): Big Too Much Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (June 2020), two trap net surveys (June 2020 and 2022), and two nearshore surveys (June 2022 and August 2021). The FIBI scores of 80 and 73 from the recent surveys were above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Big Too Much Lake. Approximately 3% of the land use in the upstream watershed is classified as developed (NLCD 2016). The most recent aquatic plant survey, a 2001 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=31), resulting in an FQI of 33, which is 70% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Big Too Much Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Big Fork River Watershed (09030006).

f. Rapid River Watershed (09030007)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/rapid-river

No applicable lakes.

g. Lower Rainy River Watershed (09030008)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-rainy-river

No applicable lakes.

h. Lake of the Woods Watershed (09030009)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lake-of-the-woods

No applicable lakes.

3. Red River of the North Basin

a. Bois de Sioux River Watershed (09020101)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/bois-de-sioux-river

No applicable lakes.

b. Mustinka River Watershed (09020102)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mustinka-river

No draft use designations.

c. Otter Tail River Watershed (09020103)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/otter-tail-river

Use designations not yet evaluated.

d. Upper Red River of the North Watershed (09020104)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-red-river-of-the-north

No applicable lakes.

e. Buffalo River Watershed (09020106)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/buffalo-river

Use designations not yet evaluated.

f. Red River of the North – Marsh River Watershed (09020107)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/red-river-of-the-north-marsh-river

No applicable lakes.

g. Wild Rice River Watershed (09020108)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/wild-rice-river

Use designations not yet evaluated.

h. Red River of the North – Sand Hill River Watershed (09020301)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/red-river-of-the-north-sand-hill-river

No draft use designations.

i. Upper/Lower Red Lake Watershed (09020302)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-lower-red-lake

Use designations not yet evaluated.

j. Red Lake River Watershed (09020303)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/red-lake-river

No applicable lakes.

k. Thief River Watershed (09020304)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/thief-river

No applicable lakes.

l. Clearwater River Watershed (09020305)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/clearwater-river

Use designations not yet evaluated.

m. Red River of the North – Grand Marais Creek Watershed (09020306)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/red-river-of-the-north-grand-marais-creek

No applicable lakes.

n. Snake River Watershed (09020309)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/snake-river-red-river-basin

No applicable lakes.

o. Red River of the North – Tamarac River Watershed (09020311)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-red-river-red-river-of-the-north-tamarac-river

No applicable lakes.

p. Two Rivers Watershed (09020312)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/two-rivers

No applicable lakes.

q. Roseau River Watershed (09020314)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/roseau-river

No applicable lakes.

4. Upper Mississippi River Basin

a. Mississippi River – Headwaters Watershed (07010101)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-headwaters

Use designations not yet evaluated.

b. Leech Lake River Watershed (07010102)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/leech-lake-river

Use designations not yet evaluated.

c. Mississippi River – Grand Rapids Watershed (07010103)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-grand-rapids

Use designations not yet evaluated.

d. Mississippi River – Brainerd Watershed (07010104)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-brainerd

Use designations not yet evaluated.

e. Pine River Watershed (07010105)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/pine-river

Use designations not yet evaluated.

f. Crow Wing River Watershed (07010106)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/crow-wing-river

Table 7. Crow Wing River Watershed (07010106) biological and habitat data associated with lakes that will be designated as Class 2Ae or 2Be (abbreviations: DOW=division of waters number, FIBI=fish index of biological integrity, STS=score the shore, FQI=floristic quality index, * indicates supplemental, historic survey data, † indicates supplemental, non-standard effort survey data).

DOW	Lake name	FIBI group	FIBI survey year(s)	FIBI score(s)	% watershed disturbance	STS score(s)	FQI % deviation from threshold
03001700	Two Inlets	2	2016, 2011*	74, 65	8	60, 66	37
03003000	Boot	2	2021, 2021, 2016	75, 79, 71	20	79, 80	37
11030400	Sylvan[8]	2	2021, 2008	72, 67	7	83	102
11030500	Gull	2	2017, 2017, 2007*	77, 68, 62	16	63	62
18037600	Upper Cullen	4	2021, 2012†*, 2003*	78, 74, 41	18	-	86
18037700	Middle Cullen	2	2021, 2003*	75, 58	17	-	72
18040900	West Twin	4	2021, 2017	59, 61	14	80	-
29002500	Ninth Crow Wing	2	2021, 2018†, 2013*	86, 58, 72	17	90	27
29003600	Eleventh Crow Wing[9]	2	2021, 2016	63, 71	13	64, 67	64
29004500	Tenth Crow Wing	4	2018, 2013†*	77, 82	12	88	21
29007200	Eighth Crow Wing	4	2018	77	17	83	27
29008700	Palmer	4	2021, 2016	66, 71	57	90, 89	34

[8] The MPCA WID database includes both basins of Sylvan Lake separately (11-0304-01 and 11-0304-02). Both basins will be assigned Class 2Be.
[9] The MPCA WID database includes both basins of Eleventh Crow Wing separately (29-0036-01 and 29-0036-02). Both basins will be assigned Class 2Ae[TLC].

DOW	Lake name	FIBI group	FIBI survey year(s)	FIBI score(s)	% watershed disturbance	STS score(s)	FQI % deviation from threshold
29009100	Seventh Crow Wing	4	2019	78	20	88	22
29009200	Fifth Crow Wing	4	2019	72	16	80	45
29009300	Sixth Crow Wing	4	2019	84	19	88	33
29016100	Long	2	2019	76	40	75	30
29018400	Blue	2	2019	75	24	78	3
29024200	Fish Hook	2	2017, 2012*, 2007*	72, 68, 73	11	59	48
29024300	Potato	2	2016, 2010*	70, 74	9	74	41
29025400	Island	2	2021, 2020†, 2010*	74, 61, 71	9	66, 69	39
29025600	Eagle	2	2020, 2017†, 2011†*	75, 36, 61	9	77	65
80003000	Lower Twin	4	2021, 2018†	71, 80	26	83	37

Two Inlets Lake (03001700): Two Inlets Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net, gill net, and nearshore surveys (July 2016). An additional survey was completed in August 2011 and is provided as supplemental historic information. The FIBI score of 74 from the recent survey was above the Exceptional Use threshold (64). The FIBI score of 65 from the supplemental historic survey was also above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Two Inlets Lake. Approximately 8% of the land use in the upstream watershed is classified as disturbed, with 3% developed, 3% pasture and hay, and 2% cultivated (NLCD 2016). Two Score the Shore surveys were completed in 2016 and 2021 and resulted in mean scores of 60 and 66 out of 100 in those respective years, indicating low to moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2011 transect survey, indicates that the lake supports a relatively diverse aquatic plant community (N=22), resulting in an FQI of 28, which is 37% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Two Inlets Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Boot Lake (03003000): Boot Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco: see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using two gill net surveys (August 2016 and August 2021), three trap net surveys (August 2016, June 2021, and August 2021), and two nearshore surveys (July 2016 and June 2021). The FIBI scores of 75, 79, and 71 were above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Boot Lake. Approximately 20% of the land use in the upstream watershed is classified as disturbed, with 6% developed, 12% pasture and hay, and 2% cultivated (NLCD 2016). Two Score the Shore surveys were completed in 2016 and 2021 and resulted in mean scores of 79 and 80 out of 100 in those respective years, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2016 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=20), resulting in an FQI of 28, which is 37% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Boot Lake with the Class 2Ae[TLC] designation. The MPCA

will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Sylvan Lake (11030400): Sylvan Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using trap net and gill net surveys (June 2021) and a nearshore survey (July 2021). An additional survey was completed in July 2008 and is provided as supplemental historic information. The FIBI score of 72 from the recent survey was above the Exceptional Use threshold (64). The FIBI score of 67 from the supplemental historic survey was also above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Sylvan Lake. Approximately 8% of the land use in the upstream watershed is classified as disturbed, with 7% developed and 1% pasture and hay (NLCD 2016). A Score the Shore survey was completed in 2016 and resulted in a mean score of 83 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2008 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=36), resulting in an FQI of 41, which is 102% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Sylvan Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Gull Lake (11030500): Gull Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (July 2017) and two nearshore surveys (August 2017). An additional survey was completed in August 2007 and is provided as supplemental historic information. The FIBI scores of 77 and 68 from the recent surveys were above the Exceptional Use threshold (64). The FIBI score of 62 from the supplemental historic survey was above the General Use threshold (45) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Gull Lake. Approximately 16% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 9% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 63 out of 100, indicating low quality lakeshore habitat. The most recent aquatic plant survey, a 1996 transect survey, indicates that the lake supports a relatively diverse aquatic plant community (N=28), resulting in an FQI of 33, which is 62% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Gull Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Upper Cullen Lake (18037600): Upper Cullen Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (July 2021) and a nearshore survey (September 2021). Two additional surveys were completed in September 2003 and July 2012 and are provided as supplemental historic information. Abundant aquatic vegetation (e.g., bulrush, cattail, and water lilies) limited seining effort, particularly during the July 2012 survey, and thereby reduced certainty associated with interpretation of that FIBI score. The FIBI score of 78 from the recent survey was above the Exceptional Use threshold (59). The FIBI score of 74 from the 2012 supplemental historic survey was also above the Exceptional Use threshold; however, this score will be given limited consideration given the low nearshore survey effort. The FIBI score of 41 from the 2003 supplemental historic survey was above the General Use threshold (38) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Upper Cullen Lake. Approximately 18% of the land use in the upstream watershed is classified as disturbed, with 10% developed, 6% pasture and hay, and 2% cultivated (NLCD

2016). Shoreline disturbance, as measured by dock density, is low, with approximately 3.3 docks per kilometer of shoreline. The most recent aquatic plant survey, a 2012 point-intercept survey, indicates that the lake supports a diverse aquatic plant community (N=34), resulting in an FQI of 38, which is 86% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Upper Cullen Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Middle Cullen Lake (18037700): Middle Cullen Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (July 2021) and a nearshore survey (September 2021). An additional survey was completed in September 2003 and is provided as supplemental historic information. The FIBI score of 75 from the recent survey was above the Exceptional Use threshold (64). The FIBI score of 58 from the supplemental historic survey was above the General Use threshold (45) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Middle Cullen Lake. Approximately 17% of the land use in the upstream watershed is classified as disturbed, with 9% developed, 6% pasture and hay, and 1% cultivated (NLCD 2016). Shoreline disturbance, as measured by dock density, is high, with approximately 14.3 docks per kilometer of shoreline. The most recent aquatic plant survey, a 2007 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=33), resulting in an FQI of 35, which is 72% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Middle Cullen Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

West Twin Lake (18040900): West Twin Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (June 2017), two trap net surveys (June 2017 and June 2021), and two nearshore surveys (July 2017 and June 2021). The FIBI scores of 61 and 59 were above or equal to the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for West Twin Lake. Approximately 14% of the land use in the upstream watershed is classified as disturbed, with 8% developed, 5% pasture and hay, and <1% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean lakewide of 80 out of 100, indicating moderate quality lakeshore habitat. Aquatic plant survey information was unavailable to evaluate diversity or calculate an FQI score. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to West Twin Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Ninth Crow Wing Lake (29002500): Ninth Crow Wing Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (August 2018), two trap net surveys (August 2018 and August 2021), and two nearshore surveys (July 2018 and August 2021). An additional survey was completed in August 2013 and is provided as supplemental historic information. Abundant aquatic vegetation (e.g., bulrush, cattail, and water lilies) and soft substrates limited seining effort, particularly during the August 2018 survey, and thereby reduced certainty associated with interpretation of that FIBI score. The FIBI score of 86 from the 2021 survey was above the Exceptional Use threshold (64). The FIBI score of 58 from the 2018 survey was above the General Use threshold (45) but below the Exceptional Use threshold; however, this score will be given limited consideration given the low nearshore survey effort. The FIBI score of 72 from the supplemental historic survey above the Exceptional Use threshold. Select stressor

and habitat information was reviewed for Ninth Crow Wing Lake. Approximately 17% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 10% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2018 and resulted in a mean score of 90 out of 100, indicating high-quality lakeshore habitat. The most recent aquatic plant survey, a 2013 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=19), resulting in an FQI of 26, which is 27% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Ninth Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Eleventh Crow Wing Lake (29003600): Eleventh Crow Wing Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using two trap net and gill net surveys (July 2016 and July 2021) and two nearshore surveys (July 2016 and August 2021). The FIBI scores of 63 and 71 were above the General Use threshold (45); both scores were above the upper limit of the 90% confidence interval (54) but only one was also above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Eleventh Crow Wing Lake. Approximately 13% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 7% pasture and hay, and 1% cultivated (NLCD 2016). Two Score the Shore surveys were completed in 2016 and 2021 and resulted in mean scores of 64 and 67 out of 100 in those respective years, indicating low to moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2016 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=21), resulting in an FQI of 27, which is 64% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Eleventh Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Tenth Crow Wing Lake (29004500): Tenth Crow Wing Lake will be designated Class 2Ae[TLC] because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (June 2018) and a nearshore survey (August 2018). An additional survey was completed in August 2013 and is provided as supplemental historic information. Due to unspecified reasons, seining effort was limited during the August 2013 survey, and thereby reduced certainty associated with interpretation of that particular FIBI score. The FIBI score of 77 from the recent survey was above the Exceptional Use threshold (59). The FIBI score of 82 from the supplemental historic survey was also above the Exceptional Use threshold; however, this score will be given limited consideration given the low nearshore survey effort. Select stressor and habitat information was reviewed for Tenth Crow Wing Lake. Approximately 12% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 7% pasture and hay, and <1% cultivated (NLCD 2016). A Score the Shore survey was completed in 2018 and resulted in a mean score of 88 out of 100, indicating high-quality lakeshore habitat. The most recent aquatic plant survey, a 2018 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=17), resulting in an FQI of 24, which is 21% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Tenth Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Eighth Crow Wing Lake (29007200): Eighth Crow Wing Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using trap net and gill net surveys (June 2018) and a nearshore survey (July 2018). The FIBI score of 77 was above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Eighth Crow Wing Lake. Approximately 17% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 10% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2018 and resulted in a mean score of 83 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2018 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=19), resulting in an FQI of 26, which is 27% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Eighth Crow Wing Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Palmer Lake (29008700): Palmer Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using two trap net and gill net surveys (June 2016 and June 2021) and two nearshore surveys (June 2016 and August 2021). The FIBI scores of 66 and 71 were above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Palmer Lake. Approximately 57% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 6% pasture and hay, and 46% cultivated (NLCD 2016). Two Score the Shore surveys were completed in 2016 and 2021 and resulted in mean scores of 90 and 89 out of 100 in those respective years, indicating high-quality lakeshore habitat. The most recent aquatic plant survey, a 2006 transect survey, indicates that the lake supports a relatively diverse aquatic plant community (N=18), resulting in an FQI of 25, which is 34% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Palmer Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Seventh Crow Wing Lake (29009100): Seventh Crow Wing Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net, gill net, and nearshore surveys (July 2019). The FIBI score of 78 was above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Seventh Crow Wing Lake. Approximately 19% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 11% pasture and hay, and 3% cultivated (NLCD 2016). A Score the Shore survey was completed in 2019 and resulted in a mean score of 88 out of 100, indicating high-quality lakeshore habitat. The most recent aquatic plant survey, a 2014 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=17), resulting in an FQI of 25, which is 22% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Seventh Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Fifth Crow Wing Lake (29009200): Fifth Crow Wing Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (August 2019) and a nearshore survey (July 2019). The FIBI score of 72 was above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Fifth Crow Wing Lake. Approximately 16% of the land use in the upstream watershed is

classified as disturbed, with 4% developed, <1% barren, 8% pasture and hay, and 3% cultivated (NLCD 2016). A Score the Shore survey was completed in 2019 and resulted in a mean score of 80 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2019 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=22), resulting in an FQI of 29, which is 45% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Fifth Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Sixth Crow Wing Lake (29009300): Sixth Crow Wing Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (August 2019) and a nearshore survey (July 2019). The FIBI score of 84 was above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Sixth Crow Wing Lake. Approximately 19% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 11% pasture and hay, and 3% cultivated (NLCD 2016). A Score the Shore survey was completed 2019 and resulted in a mean score of 88 out of 100, indicating high quality lakeshore habitat. The most recent aquatic plant survey, a 2014 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=19), resulting in an FQI of 27, which is 33% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Sixth Crow Wing Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Long Lake (29016100): Long Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a trap net, gill net, and nearshore surveys (July 2019). The FIBI score of 76 was above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Long Lake. Approximately 40% of the land use in the upstream watershed is classified as disturbed, with 7% developed, 13% pasture and hay, and 20% cultivated (NLCD 2016). A Score the Shore survey was completed to assess shoreline habitat in 2019 and resulted in a mean lakewide habitat score of 75 out of 100, indicating moderate lakeshore condition. The most recent aquatic plant survey, a 2014 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=17), resulting in an FQI of 24, which is 30% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Long Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Blue Lake (29018400): Blue Lake will be designated Class 2Ae[TLC,SRT], because it demonstrates support for coldwater species (Cisco and stream trout; see MPCA 2025), and also an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (August 2019) and a nearshore survey (July 2019). The FIBI score of 75 was above the Exceptional Use threshold (64). Select stressor and habitat information was reviewed for Blue Lake. Approximately 24% of the land use in the upstream watershed is classified as disturbed, with 8% developed, 13% pasture and hay, and 3% cultivated (NLCD 2016). A Score the Shore survey was completed in 2019 and resulted in a mean score of 78 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2014 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=14), resulting in an FQI of 21,

which is 3% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2A designation currently assigned to Blue Lake with the Class 2Ae[TLC,SRT] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Fish Hook Lake (29024200): Fish Hook Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net, gill net, and nearshore surveys (July 2017). Two additional surveys were completed in July 2007 and July 2012 and are provided as supplemental historic information. The FIBI score of 72 from the recent survey above the Exceptional Use threshold (64). The FIBI scores of 73 and 68 from the supplemental historic surveys were also above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Fish Hook Lake. Approximately 11% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 5% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 59 out of 100, indicating low-quality lakeshore habitat. The most recent aquatic plant survey, a 2017 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=23), resulting in an FQI of 30, which is 48% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Fish Hook Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Potato Lake (29024300): Potato Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net, gill net, nearshore surveys (July 2016). An additional survey was completed in July 2010 and is provided as supplemental historic information. The FIBI score of 70 from the recent survey was above the Exceptional Use threshold (64). The FIBI score of 74 from the supplemental historic survey was also above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Potato Lake. Approximately 9% of the land use in the upstream watershed is classified as disturbed, with 3% developed, 5% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2016 and resulted in a mean score of 74 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2006 MBS survey, indicates that the lake supports a relatively diverse aquatic plant community (N=25), resulting in an FQI of 28, which is 41% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Potato Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Island Lake (29025400): Island Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using trap net and gill net surveys (July 2020) and two nearshore surveys (July 2020 and July 2021). An additional survey was completed in July 2010 and is provided as supplemental historic information. Abundant aquatic vegetation (e.g., bulrush, cattail, water lilies, and wild rice) and soft substrates limited seining effort, particularly during the July 2020 survey, and thereby reduced certainty associated with interpretation of that particular FIBI score. The FIBI score of 74 from the 2021 survey was above the Exceptional Use threshold (64). The FIBI score of 61 from the 2020 survey was above the General Use threshold (45) but below the Exceptional Use threshold; however, this score will be given limited consideration given the low nearshore survey effort. The FIBI score of 71 from the supplemental historic

survey was above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Island Lake. Approximately 9% of the land use in the upstream watershed is classified as disturbed, with 3% developed, 4% pasture and hay, and 2% cultivated (NLCD 2016). Two Score the Shore surveys were completed in 2015 and 2020 and resulted in mean scores of 66 and 69 out of 100 in those respective years, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2020 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=19), resulting in an FQI of 28, which is 39% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Island Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Eagle Lake (29025600): Eagle Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (July 2017), two trap net surveys (July 2017 and July 2020), and two nearshore surveys (August 2017 and July 2020). An additional survey was completed in August 2011 and is provided as supplemental historic information. Abundant aquatic vegetation (e.g., bulrush, cattail, and water lilies) and soft substrates limited seining effort, particularly during the August 2011 and July 2017 surveys, and thereby reduced certainty associated with interpretation of those FIBI scores. The FIBI score of 75 from the 2020 survey was above the Exceptional Use threshold (64). The FIBI score of 36 from the 2017 survey was below the General Use threshold (45) and the FIBI score of 61 from the supplemental historic survey was above the General Use threshold but below the Exceptional Use threshold. The 2017 and 2011 scores will be given limited consideration given the lower than required nearshore survey effort. Select stressor and habitat information was reviewed for Eagle Lake. Approximately 9% of the land use in the upstream watershed is classified as disturbed, with 3% developed, 4% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 77 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2017 point-intercept survey, indicates that the lake supports a relatively diverse aquatic plant community (N=29), resulting in an FQI of 33, which is 65% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Eagle Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

Lower Twin Lake (80003000): Lower Twin Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (July 2018), two trap net surveys (July 2018 and July 2021), and two nearshore surveys (July 2018 and July 2021). Abundant aquatic vegetation (e.g., bulrush, cattail, and water lilies) and soft substrates limited seining effort, particularly during the July 2018 survey, and thereby reduced certainty associated with interpretation of that FIBI score. The FIBI scores of 71 in 2021 and 80 in 2018 were above the Exceptional Use threshold (59); however, the 2018 score will be given limited consideration given the low nearshore survey effort. Select stressor and habitat information was reviewed for Lower Twin Lake. Approximately 26% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 8% pasture and hay, and 13% cultivated (NLCD 2016). A Score the Shore survey was completed in 2018 and resulted in a mean score of 83 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2006 MBS survey, indicates that the lake supports a relatively diverse aquatic plant community (N=22), resulting in an FQI of 26, which is 37% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Lower Twin Lake with the Class 2Be designation. The MPCA will

make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Crow Wing River Watershed (07010106).

g. Redeye River Watershed (07010107)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/redeye-river

No draft use designations.

h. Long Prairie River Watershed (07010108)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/long-prairie-river

Table 8. Long Prairie River Watershed (07010108) biological and habitat data associated with lakes that will be designated as Class 2Ae or 2Be (abbreviations: DOW=division of waters number, FIBI=fish index of biological integrity, STS=score the shore, FQI=floristic quality index, * indicates supplemental, historic survey data, † indicates supplemental, non-standard effort survey data).

DOW	Lake name	FIBI group	FIBI survey year(s)	FIBI score(s)	% watershed disturbance	STS score(s)	FQI % deviation from threshold
21008300	Miltona	2	2023, 2019, 2007*	67, 79, 63	50	60	52
21010800	Mina	2	2023, 2022, 2020†	74, 66, 51	51	91	32
21012300	Ida	2	2022, 2019, 2007*	67, 68, 58	51	66	5
49007900	Alexander	2	2018, 2010*	70, 79	9	65	101
49012700	Shamineau	2	2022, 2021†, 2010*, 2008*	68, 62, 64, 70	23	65	55
49013300	Crookneck	4	2023, 2022, 2021	60, 60, 65	18	71	49
77012000	Charlotte	2	2022, 2018, 2012*	71, 64, 48	74	67	68

Miltona Lake (21008300): Miltona Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using two gill net surveys (August 2023 and 2019), two trap net surveys (July 2023 and August 2019), and two nearshore surveys (July 2023 and 2019). An additional survey was completed in July 2007 and is provided as supplemental historic information. The FIBI scores of 67 and 79 from the recent survey were above the Exceptional Use threshold (64). The FIBI score of 63 from the supplemental historic survey was just below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Miltona Lake. Approximately 50% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 11% pasture and hay, and 35% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 60 out of 100, indicating low quality lakeshore habitat. The most recent aquatic plant survey, a 2004 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=25), resulting in an FQI of 28, which is 52% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Miltona Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Mina Lake (21010800): Mina Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (July 2020), two trap net surveys (July 2023 and 2022), and two nearshore surveys (July 2023 and 2022). An additional survey was completed in 2020 but is considered as supporting information only as the survey effort was lower than protocol. The FIBI scores of 74 and 66 from the recent surveys were above the Exceptional Use threshold (64). The FIBI score of 51 from the supplemental historic survey was above the General Use threshold (45) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Mina Lake. Approximately 51% of the land use in the upstream watershed is classified as disturbed, with 6% developed, 12% pasture and hay, and 34% cultivated (NLCD 2016). A Score the Shore survey was completed in 2020 and resulted in a mean score of 91 out of 100, indicating high quality lakeshore habitat. The most recent aquatic plant survey, a 1997 survey conducted by the Fisheries program, indicates that the lake supports a relatively diverse aquatic plant community (N=17), resulting in an FQI of 24, which is 32% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Mina Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Ida Lake (21012300): Ida Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using two gill net surveys (August 2023 and 2019), two trap net surveys (July 2022 and August 2019), and two nearshore surveys (July 2022 and 2019). An additional survey was completed in June 2007 and is provided as supplemental historic information. The FIBI scores of 67 and 68 from the recent surveys were above the Exceptional Use threshold (64). The FIBI score of 58 from the supplemental historic survey was below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Ida Lake. Approximately 51% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 11% pasture and hay, and 36% cultivated (NLCD 2016). A Score the Shore survey was completed in 2019 and resulted in a mean score of 66 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2004 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=12), resulting in an FQI of 20, which is 5% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Ida Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Alexander Lake (49007900): Alexander Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using gill net and trap net surveys (August 2018) and a nearshore survey (July 2018). An additional survey was completed in August 2010 and is provided as supplemental historic information. The FIBI score of 70 from the recent survey was above the Exceptional Use threshold (64). The FIBI score of 79 from the supplemental historic survey was also above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Alexander Lake. Approximately 9% of the land use in the upstream watershed is classified as disturbed, with 4% developed, 3% pasture and hay, and 2% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 65 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2014 survey conducted by the Fisheries program, indicates that the lake supports a relatively diverse aquatic plant community (N=41), resulting in an FQI of 41, which is 101% higher than the threshold identified to

represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Alexander Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Shamineau Lake (49007900): Shamineau Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (July 2021), two trap net surveys (June 2022 and July 2021), and two nearshore surveys (June 2022 and July 2021). The 2021 nearshore survey had lower effort due to high water. Two additional surveys were completed in July 2010 and August 2008 and are provided as supplemental historic information. The FIBI scores of 68 and 62 from the surveys were above the General Use threshold (45) and near or above the Exceptional Use threshold (64). Two older FIBI scores of 64 and 70 from the supplemental historic survey were also equal to or above the Exceptional Use threshold. Select stressor and habitat information was reviewed for Shamineau Lake. Approximately 23% of the land use in the upstream watershed is classified as disturbed, with 5% developed, 5% pasture and hay, and 13% cultivated (NLCD 2016). A Score the Shore survey was completed in 2017 and resulted in a mean score of 65 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2014 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=26), resulting in an FQI of 30, which is 55% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Shamineau Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Crookneck Lake (49012700): Crookneck Lake will be designated Class 2Be. The biological integrity of the fish community was evaluated using a gill net survey (June 2021), two trap net surveys (July 2023 and June 2021), and three nearshore surveys (July 2023, June 2022, and July 2021). The FIBI scores of 60, 60, and 65 from the recent surveys were above the Exceptional Use threshold (59). Select stressor and habitat information was reviewed for Crookneck Lake. Approximately 18% of the land use in the upstream watershed is classified as disturbed, with 16% developed, <1% pasture and hay, and 1% cultivated (NLCD 2016). A Score the Shore survey was completed in 2022 and resulted in a mean score of 71 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2014 survey conducted by the MBS, indicates that the lake supports a relatively diverse aquatic plant community (N=27), resulting in an FQI of 29, which is 49% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Crookneck Lake with the Class 2Be designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

Charlotte Lake (77012000): Charlotte Lake will be designated Class 2Ae[TLC], because it demonstrates support for a coldwater species (Cisco; see MPCA 2025) and an exceptional cool- and warmwater fish community. The biological integrity of the cool- and warmwater fish community was evaluated using a gill net survey (June 2018), two trap net surveys (June 2022 and 2018), and two nearshore surveys (June 2022 and 2018). An additional survey was completed in June 2012 and is provided as supplemental historic information. The FIBI scores of 70 and 64 from the recent surveys were at or above the Exceptional Use threshold (64). The FIBI score of 48 from the supplemental historic survey was above the General Use threshold (45) but below the Exceptional Use threshold. Select stressor and habitat information was reviewed for Charlotte Lake. Approximately 74% of the land use in the upstream watershed is classified as disturbed, with 8% developed, 22% pasture and hay, and 44% cultivated (NLCD 2016). A Score the Shore survey was completed in 2019 and resulted in a mean score of 67 out of 100, indicating moderate quality lakeshore habitat. The most recent aquatic plant survey, a 2006 survey conducted by the Fisheries program, indicates that the lake supports a relatively diverse aquatic plant

community (N=26), resulting in an FQI of 31, which is 68% higher than the threshold identified to represent the minimum accepted state of biological condition. Considering this information, it is reasonable to replace the Class 2B designation currently assigned to Charlotte Lake with the Class 2Ae[TLC] designation. The MPCA will make this change in Minn. R. 7050.0470 by updating the beneficial use table for the Long Prairie River Watershed (07010108).

i. Mississippi River – Sartell Watershed (07010201)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-sartell

Use designations not yet evaluated.

j. Sauk Rapids Watershed (07010202)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/sauk-river

Use designations not yet evaluated.

k. Mississippi River – St. Cloud Watershed (07010203)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-st-cloud

Use designations not yet evaluated.

l. North Fork Crow River Watershed (07010204)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/north-fork-crow-river

Use designations not yet evaluated.

m. South Fork Crow River Watershed (07010205)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/south-fork-crow-river

Use designations not yet evaluated.

n. Mississippi River – Twin Cities Watershed (07010206)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-twin-cities

No draft use designations.

o. Rum River Watershed (07010207)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/rum-river

Use designations not yet evaluated.

5. Minnesota River Basin

a. Minnesota River - Headwaters Watershed (07020001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/minnesota-river-headwaters

Use designations not yet evaluated.

b. Pomme de Terre River Watershed (07020002)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/pomme-de-terre-river

Use designations not yet evaluated.

c. Lac qui Parle River Watershed (07020003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lac-qui-parle-river

Use designations not yet evaluated.

d. Minnesota River – Yellow Medicine River Watershed (07020004)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/minnesota-river-yellow-medicine-river-hawk-creek

No draft use designations.

e. Chippewa River Watershed (07020005)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/chippewa-river

Use designations not yet evaluated.

f. Redwood River Watershed (07020006)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/redwood-river

Use designations not yet evaluated.

g. Minnesota River – Mankato Watershed (07020007)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/minnesota-river-mankato

Use designations not yet evaluated.

h. Cottonwood River Watershed (07020008)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/cottonwood-river

Use designations not yet evaluated.

i. Blue Earth River Watershed (07020009)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/blue-earth-river

Use designations not yet evaluated.

j. Watonwan River Watershed (07020010)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/watonwan-river

Use designations not yet evaluated.

k. Le Sueur River Watershed (07020011)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/le-sueur-river

Use designations not yet evaluated.

l. Lower Minnesota River Watershed (07020012)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-minnesota-river

Use designations not yet evaluated.

6. Saint Croix River Basin

a. Upper St. Croix River Watershed (07030001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-st-croix-river

No applicable lakes.

b. Kettle River Watershed (07030003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/kettle-river

Use designations not yet evaluated.

c. Snake River Watershed (07030004)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/snake-river-st-croix-basin

Use designations not yet evaluated.

d. Lower St. Croix River Watershed (07030005)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-st-croix-river

Use designations not yet evaluated.

e. Mississippi River – Lake Pepin Watershed (07040001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-lake-pepin

Use designations not yet evaluated.

f. Cannon River Watershed (07040002)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/cannon-river

No draft use designations.

g. Mississippi River – Winona Watershed (07040003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-winona

No applicable lakes.

h. Zumbro River Watershed (07040004)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/zumbro-river

No applicable lakes.

i. Mississippi River – La Crescent Watershed (07040006)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-la-crescent

No applicable lakes.

j. Root River Watershed (07040008)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/root-river

No applicable lakes.

k. Mississippi River – Reno Watershed (07060001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/mississippi-river-reno

No applicable lakes.

l. Upper Iowa River Watershed (07060002)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-iowa-river

No applicable lakes.

7. Cedar-Des Moines Rivers Basin

a. Upper Wapsipinicon River Watershed (07080102)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-wapsipinicon-river

No applicable lakes.

b. Cedar River Watershed (07080201)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/cedar-river

No applicable lakes.

c. Shell Rock River Watershed (07080202)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/shell-rock-river

Use designations not yet evaluated.

d. Winnebago River Watershed (07080203)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/winnebago-river

No applicable lakes.

e. Des Moines River - Headwaters Watershed (07100001)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/des-moines-river-headwaters

Use designations not yet evaluated.

f. Lower Des Moines River Watershed (07100002)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-des-moines-river

No applicable lakes.

g. East Fork Des Moines River Watershed (07100003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/east-fork-des-moines-river

Use designations not yet evaluated.

8. Missouri River Basin

a. Upper Big Sioux River Watershed (10170202)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/upper-big-sioux-river

No applicable lakes.

b. Lower Big Sioux River Watershed (10170203)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/lower-big-sioux-river

No applicable lakes.

c. Rock River Watershed (10170204)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/rock-river

No applicable lakes.

d. Little Sioux River Watershed (10230003)

MPCA webpage: https://www.pca.state.mn.us/watershed-information/little-sioux-river

No draft use designations.

Appendix B: Confirmed General Use designations

In addition to the proposed Exceptional Use designations in this document, the TALU reviews also determined that 202 lake WIDs (129,446 acres) that were monitored in 2020-2022 (and subsequently assessed in 2022-2024) should be confirmed as General Use waters (Table 9). The list of these lakes is provided in Table 9.

Table 9. List of lakes from the 2020, 2021 and 2022 Intensive Watershed Monitoring framework watersheds with confirmed General Use designations. Abbreviations: WID = waterbody identification code; 2Bg = General Use cool/warm water habitat; 2Bdg = General Use cool/warm water habitat also protected as a source for drinking water; 2Ag = General Use cold water habitat.

WID	Waterbody name	Use	Acres	County
Minn. R. 7050.0470, subp. 1. Lake Superior Basin				
1.A.(1) Lake Superior - North (04010101)				
None				
1.A.(2) Lake Superior - South (04010102)				
None				
1.A.(3) St. Louis River (04010201)				
None				
1.A.(4) Cloquet River (04010202)				
None				
1.A.(5) Nemadji River (04010301)				
09-0008-00	Chub - 2 MI SW OF CARLTON	2Bg	302.99	Carlton
Minn. R. 7050.0470, subp. 2. Lake of the Woods Basin				
2.A.(1) Rainy River - Headwaters (09030001)				
None				
2.A.(2) Vermilion River (09030002)				
None				
2.A.(3) Rainy River - Rainy Lake (09030003)				
None				
2.A.(4) Little Fork River (09030005)				
None				
2.A.(5) Big Fork River (09030006)				
31-0805-00	Arrowhead - 6.5 MI SE OF WIRT	2Bg	129.32	Itasca
31-0197-00	Battle - EFFIE	2Bg	236.93	Itasca
31-0726-00	Bello - 8 MI SW OF BIGFORK	2Ag[TLC]	502.17	Itasca
31-0671-00	Big Island - 5 MI E OF MARCELL	2Bg	245.08	Itasca
31-0813-00	Bowstring - 14 MI NW OF DEER RIVER	2Bg	9198.42	Itasca
31-0524-01	Coon - 4 SE OF BIGFORK	2Bg	374.96	Itasca
31-0543-00	Crooked - MARCELL	2Bg	132.68	Itasca
31-0334-00	Deer - 14 MI NE OF BIGFORK	2Ag[TLC]	1830.48	Itasca
31-0454-00	Eagle - 20 MI N OF COLERAINE	2Bg	276.91	Itasca
31-0782-00	Gunderson - 6 MI SW OF BIGFORK	2Bg	175.02	Itasca
31-0913-00	Island - 4 MI S OF NORTHOME	2Bg	2935.99	Itasca
31-0786-00	Jessie - 18 MI N OF DEER RIVER	2Ag[TLC]	1742.71	Itasca
31-0758-00	Little Bowstring - 3 MI SE OF BOWSTRING	2Ag[TLC]	316.17	Itasca
31-0784-00	Little Jessie - 1 MI NNW OF BOWSTRING	2Ag[TLC]	614.54	Itasca
31-0773-00	Maple - 2 MI SW OF JAYNES	2Ag[TLC]	244.56	Itasca
31-0898-00	Moose - 7 MI E OF ORTH	2Bg	400.69	Itasca; Koochiching
31-0339-00	Pickerel - 15 MI NE OF BIGFORK	2Ag[TLC]	233.65	Itasca

WID	Waterbody name	Use	Acres	County
31-0524-02	Sandwick - 4 SE OF BIGFORK	2Bg	211.19	Itasca
31-0910-00	Shallow Pond - ALVWOOD	2Bg	217.22	Itasca
31-0843-00	Whitefish - WIRT	2Ag[TLC]	506.94	Itasca
None				
2.A.(7) Rainy River - Lower (09030008)				
None				
2.A.(8) Lake of the Woods (09030009)				
None				
None				
26-0185-00	Cottonwood - 5 MI NW OF DONNELLY	2Bg	247.48	Grant; Stevens
None				
None				
None				
3.A.(6) Red River of the North - Marsh River (09020107)				
None				
None				
60-0202-00	Sarah - 4 MI S OF ERSKINE	2Bg	310.49	Polk
60-0217-00	Union - 7 MI SE OF MENTOR	2Bg	798.58	Polk
None				
None				
None				
None				
None				
None				
None				
None				
None				
Minn. R. 7050.0470, subp. 4. Upper Mississippi River Basin				
4.A.(1) Mississippi River - Headwaters (07010101)				
None				
4.A.(2) Leech Lake River (07010102)				

WID	Waterbody name	Use	Acres	County
None				
4.A.(3) Mississippi River – Grand Rapids (07010103)				
None				
4.A.(4) Mississippi River - Brainerd (07010104)				
None				
4.A.(5) Pine River (07010105)				
None				
4.A.(6) Crow Wing River (07010106)				
03-0127-00	Bass - 1 MI N OF SNELLMAN	2Bg	125.54	Becker
29-0146-00	Belle Taine - 3 MI E OF DORSET	2Bg	1488.04	Hubbard
29-0032-00	Big Bass - 8 MI SW OF AKELEY	2Bg	131.87	Hubbard
29-0185-00	Big Sand - 5 MI NE OF PARK RAPIDS	2Ag[TLC]	1628.76	Hubbard
29-0143-00	Big Stony - 5 MI NE OF HUBBARD	2Bg	351.99	Hubbard
80-0034-00	Blueberry - 3 MI N OF MENAHGA	2Bg	548.58	Wadena
29-0162-00	Boulder - 1 MI NE OF DORSET	2Bg	323.52	Hubbard
18-0374-00	Clark - AT LAKE HUBERT (TOWN)	2Bg	301.31	Crow Wing
29-0110-00	Dead - 5 MI NE OF NEVIS	2Bg	133.29	Hubbard
29-0142-00	Duck - 9 MI SE OF PARK RAPIDS	2Bg	329.50	Hubbard; Wadena
29-0101-01	East Crooked - 3 MI NW OF NEVIS	2Ag[TLC]	360.90	Hubbard
18-0407-00	East Twin - NISSWA	2Bg	154.93	Crow Wing
18-0305-00	Edward - 8 MI N OF BRAINERD	2Ag[TLC]	2579.39	Crow Wing
29-0086-00	First Crow Wing - 5 MI W OF BADOURA	2Bg	521.34	Hubbard
29-0078-00	Fourth Crow Wing - 5 MI S OF NEVIS	2Bg	456.69	Hubbard
18-0338-00	Gladstone - 4 MI NE OF NISSWA	2Bg	432.31	Crow Wing
11-0209-00	Hardy - IN BAXTER	2Bg	100.80	Cass; Crow Wing
29-0249-00	Hinds - 6 MI S OF PARK RAPIDS	2Bg	306.22	Hubbard
18-0375-00	Hubert - 2 MI SE OF NISSWA	2Ag[TLC]	1287.61	Crow Wing
29-0088-00	Island - 7 MI S OF NEVIS	2Bg	222.61	Hubbard
29-0313-00	Little Mantrap - 15 MI NW OF PARK RPDS	2Bg	366.54	Becker; Hubbard
29-0150-00	Little Sand - 2 MI NE OF DORSET	2Ag[TLC]	408.01	Hubbard
15-0068-00	Long Lost - 9 MI S OF ZERKEL	2Bg	379.98	Clearwater
29-0180-00	Lower Bottle - 8 MI NE OF PARK RAPIDS	2Ag[TLC]	402.62	Hubbard
18-0403-00	Lower Cullen - 1 MI N OF NISSWA	2Ag[TLC]	562.96	Crow Wing
29-0151-01	MANTRAP (EAST BASIN) - 8 MI N OF DORSET	2Ag[TLC]	649.31	Hubbard
29-0151-05	MANTRAP (HOME BAY) - 8 MI N OF DORSET	2Ag[TLC]	74.78	Hubbard
29-0151-02	Mantrap (Middle Basin - 8 MI N OF DORSET	2Ag[TLC]	749.33	Hubbard
29-0151-03	MANTRAP (MIRROR BAY) - 7 MI N OF DORSET	2Ag[TLC]	34.67	Hubbard
29-0151-04	MANTRAP (WEST ARM) - 8 MI N OF DORSET	2Ag[TLC]	191.61	Hubbard
11-0222-00	Margaret - AT LAKE SHORE (TOWN)	2Ag[TLC]	242.63	Cass
18-0408-00	Mayo - 3 MI S OF PEQUOT LAKES	2Bg	161.58	Cass; Crow Wing
18-0387-02	Middle Whipple - AT BAXTER MN	2Bg	156.00	Crow Wing
18-0399-00	Nisswa - AT NISSWA	2Bg	216.93	Crow Wing
18-0372-00	North Long - 6 MI N OF BRAINERD	2Ag[TLC]	6132.80	Crow Wing
29-0178-00	Pickerel - PARK RAPIDS	2Bg	292.15	Hubbard
11-0220-00	Ray - 1 MI E OF LAKE SHORE	2Bg	141.14	Cass; Crow Wing
18-0373-00	Round - 3 MI S OF NISSWA	2Ag[TLC]	1651.61	Crow Wing
18-0398-00	Roy - 1 MI W OF NISSWA	2Bg	315.17	Crow Wing; Cass
29-0085-00	Second Crow Wing - 8 MI S OF NEVIS	2Ag[TLC]	224.13	Hubbard
03-0102-00	Shell - 4 MI NW OF SNELLMAN	2Bg	3108.61	Becker

WID	Waterbody name	Use	Acres	County
18-0404-00	Sibley - AT PEQUOT LAKES	2Bg	417.85	Crow Wing; Cass
11-0500-00	Spider - PINE RIVER	2Bg	136.78	Cass
29-0117-02	SPIDER (EAST BAY) - 2 MI N OF NEVIS	2Ag[TLC]	104.23	Hubbard
29-0117-01	SPIDER (NE/SW BAY) - 2 MI N OF NEVIS	2Ag[TLC]	478.61	Hubbard
03-0010-00	Straight - AT OSAGE	2Ag[TLC]	479.23	Becker
29-0077-00	Third Crow Wing - 6 MI S OF NEVIS	2Ag[TLC]	643.96	Hubbard
29-0148-00	Upper Bottle - 9 MI NE OF PARK RAPIDS	2Ag[TLC]	326.51	Hubbard
11-0218-00	Upper Gull - AT LAKE SHORE (TOWN)	2Ag[TLC]	418.24	Cass
29-0101-03	West Crooked - 3 MI NW OF NEVIS	2Bg	245.13	Hubbard
18-0379-00	White Sand - AT BAXTER	2Bg	426.73	Crow Wing
4.A.(7) Redeye River (07010107)				
56-0031-00	Adley - PARKERS PRAIRIE	2Bg	208.13	Otter Tail
56-0200-00	Donalds - OTTERTAIL CITY	2Bg	184.18	Otter Tail
56-0116-02	East Leaf - 6 MI N OF HENNING	2Ag[TLC]	411.60	Otter Tail
56-0116-01	Middle Leaf - 6 MI N OF HENNING	2Ag[TLC]	396.20	Otter Tail
56-0140-01	Portage (main bay) - AT OTTERTAIL MN	2Bg	257.82	Otter Tail
56-0114-00	West Leaf - 7 MI NW OF HENNING	2Ag[TLC]	696.90	Otter Tail
4.A.(8) Long Prairie River (07010108)				
21-0053-00	Agnes - IN ALEXANDRIA	2Bg	135.28	Douglas
21-0085-00	Andrew - 2 MI SW OF ALEXANDRIA	2Ag[TLC]	948.09	Douglas
21-0151-00	Blackwell - HOLMES CITY	2Bg	293.77	Douglas
21-0102-00	Brophy - 3 MI W OF ALEXANDRIA	2Ag[TLC]	290.05	Douglas
21-0049-00	Burgen - 3 MI SE OF ALEXANDRIA	2Ag[TLC]	171.20	Douglas
21-0057-00	Carlos - 2 MI W OF CARLOS	2Ag[TLC]	2611.03	Douglas
77-0046-00	Coal - BROWERVILLE	2Bg	165.21	Todd
21-0103-00	Cowdrey - 1 MI NW OF ALEXANDRIA	2Ag[TLC]	239.29	Douglas
21-0199-02	Crooked (East Crooked) - 1 MI NW OF HOLMES CITY	2Bg	108.99	Douglas
21-0199-01	Crooked (Northwest Bay) - 1 MI NW OF HOLMES CITY	2Bg	164.52	Douglas
21-0080-00	Darling - 1 MI NW OF ALEXANDRIA	2Ag[TLC]	1043.96	Douglas
77-0076-00	Fawn - LINCOLN	2Bg	120.89	Todd
49-0137-00	Fish Trap - 7 MI S OF MOTLEY	2Ag[TLC]	1150.87	Morrison
21-0052-00	Geneva - AT ALEXANDRIA	2Ag[TLC]	650.78	Douglas
21-0150-00	Grants - HOLMES CITY	2Bg	173.80	Douglas
21-0051-00	Henry - AT ALEXANDRIA	2Bg	149.74	Douglas
77-0128-00	Horseshoe - 3 MI NE OF BROWERVILLE	2Bg	113.01	Todd
21-0076-00	Irene - 1 MI NW OF MILTONA	2Ag[TLC]	641.94	Douglas
21-0055-00	Jessie - 4 MI E OF ALEXANDRIA	2Bg	113.90	Douglas
77-0105-00	Latimer - 3 MI S OF LONG PRAIRIE	2Bg	200.36	Todd
21-0106-01	LATOKA (NORTH BAY) - 4 MI W OF ALEXANDRIA	2Ag[TLC]	568.41	Douglas
21-0106-02	LATOKA (SOUTH BAY) - 4 MI W OF ALEXANDRIA	2Ag[TLC]	192.37	Douglas
21-0056-00	Le Homme Dieu - AT ALEXANDRIA	2Ag[TLC]	1798.27	Douglas
21-0144-01	LOBSTER (EAST BAY) - 6 MI S OF GARFIELD	2Ag[TLC]	703.21	Douglas
21-0144-02	LOBSTER (WEST BAY) - 6 MI S OF GARFIELD	2Ag[TLC]	601.98	Douglas
21-0094-00	Louise - 4 MI NW OF ALEXANDRIA	2Ag[TLC]	208.99	Douglas
21-0092-00	Mary - 2 MI SW OF ALEXANDRIA	2Bg	2433.43	Douglas
21-0180-00	Mill - 7 MI S OF GARFIELD	2Ag[TLC]	438.25	Douglas
77-0050-00	Mill - LONG PRAIRIE	2Bg	161.65	Todd
21-0095-00	North Union - 3 MI NW OF ALEXANDRIA	2Ag[TLC]	116.58	Douglas
21-0140-00	Pocket - 7 MI N OF LOWRY	2Bg	255.74	Douglas

WID	Waterbody name	Use	Acres	County
49-0131-00	Round - PILLAGER	2Bg	94.72	Morrison
77-0066-00	Thunder - BROWERVILLE	2Bg	208.62	Todd
77-0088-00	Turtle - BROWERVILLE	2Ag[TLC]	109.37	Todd
21-0041-00	Union - 2 MI N OF FORADA	2Bg	104.65	Douglas
21-0073-00	Vermont - 5 MI NW OF MILTONA	2Bg	319.95	Douglas
21-0054-00	Victoria - AT ALEXANDRIA	2Ag[TLC]	417.55	Douglas
21-0081-00	Winona - IN ALEXANDRIA	2Bg	211.26	Douglas
4.A.(9) Mississippi River - Sartell (07010201)				
None				
4.A.(10) Sauk River (07010202)				
None				
4.A.(11) Mississippi River - St. Cloud (07010203)				
None				
4.A.(12) North Fork Crow River (07010204)				
None				
4.A.(13) South Fork Crow River (07010205)				
None				
4.A.(14) Mississippi River - Twin Cities (07010206)				
62-0002-00	Bald Eagle - AT WHITE BEAR LAKE	2Bg	1011.93	Anoka; Ramsey; Washington
27-0031-00	Bde Maka Ska - IN MINNEAPOLIS	2Bg	419.88	Hennepin
27-0039-00	Cedar - IN MINNEAPOLIS	2Bg	169.60	Hennepin
27-0137-00	Christmas - IN SHOREWOOD	2Bg	259.93	Carver; Hennepin
82-0163-00	Clear - 1 MI SW OF FOREST LAKE	2Bg	432.97	Washington
27-0181-00	Dutch - AT MOUND	2Bg	160.59	Hennepin
27-0111-01	Eagle - IN MAPLE GROVE	2Bg	282.23	Hennepin
10-0044-02	East Auburn - IN VICTORIA	2Bg	136.31	Carver
27-0118-00	Fish - IN MAPLE GROVE	2Bg	229.16	Hennepin
27-0139-00	Forest - 1 MI N OF SPRING PARK	2Bg	87.73	Hennepin
62-0007-00	Gervais - IN LITTLE CANADA	2Bg	228.77	Ramsey
02-0053-00	Ham - AT HAM LAKE	2Bg	169.20	Anoka
27-0016-00	Harriet - IN MINNEAPOLIS	2Bg	340.31	Hennepin
27-0040-00	Lake of the Isles - IN MINNEAPOLIS	2Bg	119.77	Hennepin
27-0160-00	Long - AT LONG LAKE	2Bg	277.53	Hennepin
27-0042-03	Lower Twin - AT CRYSTAL	2Bg	29.37	Hennepin
27-0104-00	Medicine - IN MEDICINE LAKE	2Bg	907.12	Hennepin
27-0042-02	Middle Twin - AT CRYSTAL	2Bg	56.00	Hennepin
27-0133-06	Minnetonka-Black Lake - IN MOUND	2Bg	97.44	Hennepin
27-0133-03	Minnetonka-Carsons Bay - IN DEEPHAVEN	2Bg	108.92	Hennepin
27-0133-10	Minnetonka-Crystal Bay - AT ORONO	2Bg	805.18	Hennepin
27-0133-08	Minnetonka-Emerald Lake - IN MOUND	2Bg	13.91	Hennepin
27-0133-01	Minnetonka-Grays Bay - AT WAYZATA	2Bg	184.23	Hennepin
27-0133-09	Minnetonka-Halsteds Bay - 1 MI SW OF MOUND	2Bg	571.26	Hennepin
27-0133-15	Minnetonka-Jennings Bay - AT MOUND	2Bg	300.23	Hennepin
27-0133-02	Minnetonka-Lower Lake - AT ORONO	2Bg	5908.59	Hennepin
27-0133-11	Minnetonka-Maxwell Bay - IN ORONO	2Bg	300.92	Hennepin
27-0133-13	Minnetonka-North Arm - IN ORONO	2Bg	314.10	Hennepin
27-0133-07	Minnetonka-Seton Lake - IN MOUND	2Bg	42.72	Hennepin
62-0057-00	Josephine - IN ROSEVILLE	2Bg	111.32	Ramsey

WID	Waterbody name	Use	Acres	County
27-0133-04	Minnetonka-St. Albans Bay - 1 MI NE EXCELS'R	2Bg	160.12	Hennepin
27-0133-12	Minnetonka-Stubbs Bay - IN ORONO	2Bg	196.94	Hennepin
62-0078-00	Johanna - IN ARDEN HILLS	2Bg	206.16	Ramsey
27-0133-05	Minnetonka-Upper Lake - 1.5 MI SE OF MOUND	2Bg	4229.20	Carver; Hennepin
27-0133-14	Minnetonka-West Arm - AT MOUND	2Bg	807.78	Hennepin
10-0009-00	Minnewashta - 2 MI E OF ZUMBRO HGHTS	2Bg	659.60	Carver
27-0019-00	Nokomis - IN MINNEAPOLIS	2Bg	201.25	Hennepin
62-0056-00	Owasso - IN SHOREVIEW	2Bg	366.65	Ramsey
10-0042-00	Parley - 3 MI S ST BONIFACIUS	2Bg	253.20	Carver; Hennepin
62-0013-00	Phalen - IN ST. PAUL	2Bg	191.56	Ramsey
10-0053-00	Piersons - 2 MI SW OF VICTORIA	2Bg	255.64	Carver
10-0045-00	Steiger - AT VICTORIA	2Bg	162.19	Carver
27-0141-00	Tanager - 2.5 MI SW OF WAYZATA	2Bg	51.24	Hennepin
62-0061-00	Turtle - IN SHOREVIEW	2Bg	439.28	Ramsey
27-0042-01	Upper Twin - AT CRYSTAL	2Bg	116.19	Hennepin
10-0048-00	Wassermann - 1 MI SW OF VICTORIA	2Bg	169.08	Carver
27-0117-00	Weaver - IN MAPLE GROVE	2Bg	144.53	Hennepin
10-0044-01	West Auburn - AT VICTORIA	2Bg	137.90	Carver
82-0167-00	White Bear - IN WHITE BEAR LAKE	2Bg	2408.67	Ramsey; Washington
10-0041-00	Zumbra-Sunny - 1 MI N OF VICTORIA	2Bg	259.85	Carver; Hennepin
4.A.(15) Rum River (07010207)				
None				
Minn. R. 7050.0470, subp. 5. Minnesota River Basin				
5.A.(1) Minnesota River – Headwaters (07020001)				
None				
5.A.(2) Pomme de Terre River (07020002)				
None				
5.A.(3) Lac qui Parle River (07020003)				
None				
5.A.(4) Minnesota River - Yellow Medicine River (07020004)				
34-0171-00	Eagle - 1 MI N OF WILLMAR	2Bg	837.15	Kandiyohi
34-0192-00	Long - 2 MI N OF WILLMAR	2Bg	1522.78	Kandiyohi
41-0067-00	Perch - IVANHOE	2Bg	163.06	Lincoln
41-0089-00	Shaokatan - 7 MI SW OF IVANHOE	2Bg	984.93	Lincoln
5.A.(5) Chippewa River (07020005)				
None				
5.A.(6) Redwood River (07020006)				
None				
5.A.(7) Minnesota River - Mankato (07020007)				
None				
5.A.(8) Cottonwood River (07020008)				
None				
5.A.(9) Blue Earth River (07020009)				
None				
5.A.(10) Watonwan River (07020010)				
None				
5.A.(11) Le Sueur River (07020011)				
None				
5.A.(12) Minnesota River – Lower (07020012)				

WID	Waterbody name	Use	Acres	County
None				
Minn. R. 7050.0470, subp. 6. Saint Croix River Basin				
6.A.(1) Upper St. Croix River (07030001)				
None				
6.A.(2) Kettle River (07030003)				
None				
6.A.(3) Snake River (07030004)				
None				
6.A.(4) Lower St. Croix River (07030005)				
None				
Minn. R. 7050.0470, subp. 7. Lower Mississippi River Basin				
7.A.(1) Mississippi River - Lake Pepin (07040001)				
None				
7.A.(2) Cannon River (07040002)				
74-0023-00	Beaver - 5 MI NW OF ELLENDALE	2Bg	95.24	Steele
66-0052-00	Cedar - 5 MI W OF FARIBAULT	2Bg	879.40	Rice
81-0014-01	Clear - Near Waseca	2Bg	631.51	Waseca
66-0014-00	Dudley - 5.5 MI NW OF FARIBAULT	2Bg	62.38	Rice
40-0092-01	East Jefferson - 5 MI SE OF CLEVELAND	2Bg	661.45	Le Sueur
40-0051-00	Fish - 2 MI NNE OF ELYSIAN	2Bg	73.64	Le Sueur
66-0029-00	Fox - 2 MI S OF MILLERSBURG	2Bg	306.57	Rice
40-0057-00	Frances - 1 MI NW OF ELYSIAN	2Bg	862.68	Le Sueur
66-0038-00	French - 4 MI NW OF FARIBAULT	2Bg	873.48	Rice
40-0063-00	German - 4 MI NW OF ELYSIAN	2Bg	783.86	Le Sueur
66-0047-00	Hunt - 9 MI NW OF FARIBAULT	2Bg	174.20	Rice
66-0015-00	Kelly - 4 MI NW OF FAIRBAULT	2Bg	63.24	Rice
66-0039-00	Mazaska - AT SHIELDSVILLE	2Bg	669.19	Rice
40-0056-00	Rays - ELYSIAN	2Bg	151.12	Le Sueur
66-0018-00	Roberds - 2 MI NW OF FARIBAULT	2Bg	618.89	Rice
40-0039-00	Roemhildts - ELYSIAN	2Bg	67.34	Le Sueur
66-0055-00	Shields - 7 MI NW OF FARIBAULT	2Bg	933.01	Rice
40-0031-00	Tetonka - AT WATERVILLE	2Bg	1336.64	Le Sueur
40-0002-00	Upper Sakatah - AT WATERVILLE	2Bg	879.65	Le Sueur; Rice
40-0033-00	Volney - 4 MI SE OF LE CENTER	2Bg	259.29	Le Sueur
40-0092-02	West Jefferson - 6 MI SE O CLEVELND	2Bg	382.77	Le Sueur
7.A.(3) Mississippi River – Winona (07040003)				
None				
7.A.(4) Zumbro River (07040004)				
None				
7.A.(5) Mississippi River - La Crescent (07040006)				
None				
7.A.(6) Root River (07040008)				
None				
7.A.(7) Mississippi River - Reno (07060001)				
None				
7.A.(8) Upper Iowa River (07060002)				
None				
Minn. R. 7050.0470, subp. 8. Cedar-Des Moines Rivers Basin				
8.A.(1) Upper Wapsipinicon River (07080102)				

WID	Waterbody name	Use	Acres	County
None				
8.A.(2) Cedar River (07080201)				
None				
8.A.(3) Shell Rock River (07080202)				
None				
8.A.(4) Winnebago River (07080203)				
None				
8.A.(5) Des Moines River - Headwaters (07100001)				
None				
8.A.(6) Lower Des Moines River (07100002)				
None				
8.A.(7) East Fork Des Moines River (07100003)				
None				
Minn. R. 7050.0470, subp. 9. Missouri River Basin				
9.A.(1) Upper Big Sioux River (10170202)				
None				
9.A.(2) Lower Big Sioux River (10170203)				
None				
9.A.(3) Rock River (10170204)				
None				
9.A.(4) Little Sioux River (10230003)				
32-0022-00	Clear - 3 MI W OF JACKSON	2Bg	426.05	Jackson
32-0024-00	Little Spirit - 10 MI SW OF JACKSON	2Bg	599.06	Jackson
32-0020-00	Loon - 8 MI SW OF JACKSON	2Bg	698.48	Jackson
53-0028-00	Okabena - AT WORTHINGTON	2Bg	759.20	Nobles
32-0069-00	Round - 3 MI NE OF ROUND LAKE	2Bg	905.96	Jackson

November 2026

Lake Index of Biological Integrity (IBI) Nearshore Sampling Manual



DEPARTMENT OF NATURAL RESOURCES

WILDLIFE & SPORT FISH RESTORATION

CLEAN WATER LAND & LEGACY AMENDMENT

Fisheries Lake Biological Monitoring and Assessment (LBMA) Program
Minnesota Department of Natural Resources
1601 Minnesota Drive
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Cover photo—IBI interns seining along a shoreline on Ten Mile Lake.

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Purpose

To describe the methods used by the Minnesota Department of Natural Resources (MNDNR) Lake Biological Monitoring and Assessment (LBMA) Program to collect fish index of biological integrity (IBI) fish community information using seining and backpack electrofishing at nearshore lake monitoring sites.

General Information

The LBMA Program has previously developed fish-based IBIs for four types of Minnesota lakes (Bacigalupi et al. 2021). Results from ongoing lake IBI monitoring are now used to assess aquatic life during the Minnesota Pollution Control Agency's (MPCA) watershed assessment process. To ensure consistency in data collection, this manual provides information regarding the procedures used during an IBI survey to sample the nearshore fish community using backpack electrofishing units, seines, and in some instances, quarter-inch trap nets. Sampling procedures for the other gear types used in an IBI but collected during a standard survey (i.e., gill netting and trap netting) are outlined in the Manual of Instructions for Lake Survey (MNDNR 2017).

Requirements

- Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in biology, fisheries, fish and wildlife, or a closely related specialization, including completion of specific fisheries coursework. They must have completed training in fish community sampling methodology and fish taxonomy. Field crew leaders should also be familiar with operation of boats and outboard motors and possess excellent map reading skills and a demonstrated proficiency in the use of a GPS.
- Qualifications of interns: An intern must be a student at an accredited educational institution, possess excellent human relation and communication skills, and be majoring in biology, natural resources, fisheries or wildlife management, recreation resource management, ecology, environmental science, or a related degree.
- General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity, including wading through dense vegetation, muck, boulders, etc. while wearing a backpack electrofishing unit or pulling a seine.

Responsibilities

- Field crew leader: Implements the procedures outlined in this manual and ensures that the data generated meets the standards and objectives of the LBMA Program.
- Interns: Implement the procedures outlined in this manual, including preparing and maintaining equipment, and collecting and recording data.
- Crew size: A minimum of two individuals (i.e., one field crew leader and one specialist, technician, or intern) are necessary to conduct nearshore sampling associated with an IBI survey. A crew of three or more individuals can be helpful for sampling difficult sites.

Quality Assurance and Quality Control (QA/QC)

Compliance with the procedures outlined in this manual will be maintained through periodic reviews. Crew leaders and interns will conduct periodic self-checks by comparing their results with other trained personnel (i.e., other field crew leaders) and with results from the voucher verification process. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer's manuals.

In addition to adhering to the specific requirements of this sampling manual, the minimum QA/QC requirements for this activity are as follows:

- Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.
- QC samples: Ten percent of lakes sampled in any given year are re-sampled within the season or in the subsequent season as a means of determining sampling error and temporal variability. The LBMA Supervisor will assign resurveys and coordinate with affected Area Fisheries Offices. In most cases LBMA Program crews will conduct the repeat surveys.
- Verification: The field crew leader will conduct periodic reviews of interns to ensure that procedures in this manual are followed.

Training

All inexperienced personnel will receive instruction from a trainer designated by the LBMA Program Supervisor. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

Equipment List

- ☐ Boat
- ☐ PFDs
- ☐ Waders
- ☐ Backpack electrofishing unit and associated cathode and anode (with either a diamond or a round electrode)
- ☐ Kill switch for backpack electrofishing unit, if using from the boat
- ☐ Rubberized or PVC linesmen gloves
- ☐ Polarized sunglasses
- ☐ 1–2 large dip nets (1/8-inch mesh net)
- ☐ Seines:
    - ☐ 15-foot bag seine = 15 feet x 5 feet, 1/8-inch mesh
    - ☐ 50-foot bag seine = 50 feet x 5 feet, 1/8-inch mesh
- ☐ Mini fyke nets with floats and anchors (for Lake Class 1–19 lakes only; see **Appendix A**. Nearshore Sampling and Voucher Protocol Modification for Boreal Shield Lakes)
- ☐ GPS
- ☐ Sorting buckets (5 or more)
- ☐ Small minnow dip net and/or sieve
- ☐ 100-foot rope with tent spikes on each end, tape measure, or range finder
- ☐ Field computer
- ☐ Push pole (12-foot pole with foot attachment)
- ☐ Batteries for:
    - ☐ GPS
    - ☐ Backpack electrofishing unit

- ☐ Fish identification tools
- ☐ Plastic bottles (approved for chemical storage) *(e.g., Fisher Scientific catalog number 02-895-1C)*
- ☐ Formalin (10%)
- ☐ PPE for formalin handling (gloves and goggles)
- ☐ Clam boil or other loose mesh bags for unknown voucher specimens—*optional, only use for unknowns*
- ☐ Field data sheets (**Appendix B**. Seining and Electrofishing Field Data Sheet and Voucher Bottle Labels) printed on waterproof paper (e.g., *Rite in the Rain (http://www.riteintherain.com/) catalog number 8511*)
- ☐ Voucher bottle labels (**Appendix B**. Seining and Electrofishing Field Data Sheet and Voucher Bottle Labels) printed on Resistall paper (e.g., *University Products (Holyoke, MA) catalog number 219-368511*)

*See Section of Fisheries Safety Manual (MNDNR 2020) for backpack electrofishing approved gear.

Lake Selection

A lake may be considered for evaluation by a fish-based IBI if all of the following criteria are met:

- Is classified as Schupp Lake Class 20–43 lake (Schupp Lake Class and IBI lake group assignments are available on the Minnesota Geospatial Commons (DNR Hydrography–All Water Features and Lakes with DNR Fisheries IBI Scores, respectively)). Additional information regarding which IBI group and model to use is found in Table 1.
- Has surface area greater than or equal to 100 acres
- Has not experienced significant naturally induced winterkill (resulting from shallow minimum depth and involving suspected loss of species and lack of year classes within the previous decade) or has not been reclaimed
- Is not legally classified as a reservoir or does not have a strong riverine influence (indicated by a fish community dominated by riverine species)

Lakes that are eligible for an IBI survey should be surveyed within the MPCA watershed assessment window. Preferably, nearshore surveys (i.e., backpack electrofishing and seining) and standard lake surveys (i.e., trap netting and gill netting) should be done in the same sampling season; however, a six-year window is acceptable for pairing gears.

Table 1. Fish index of biological integrity (IBI) lake groups (and respective IBI models) and descriptions.

IBI group/model	Short description	Long description
2	Deep, complex	Deepest, high shoreline development index, tend to stratify (Schupp Lake Classes 22, 23, 24, 25, 27; can also include Schupp Lake Classes 20, 21, 26)
4	Deep, simple	Deep, lower shoreline development index, tend to stratify, primarily central and northern Minnesota (Schupp Lake Classes 28, 29, 30, 31, 32)
5	Moderately shallow, vegetated	Moderate depth, often heavily vegetated, primarily central and northern Minnesota (Schupp Lake Classes 33, 34, 35, 36, 37, 39)
7	Shallow, productive	Shallow (>80% littoral), primarily southern and western Minnesota (Schupp Lake Classes 38, 40, 41, 42, 43)

Sampling Stations

Nearshore sampling stations are equally spaced along the shoreline of a lake from a random starting point. Once established, these sampling station locations are to be used for future nearshore surveys. The number of sampling stations required per lake is based on the lake (or basin's) surface acreage (Table 2). Additional details regarding methods used during IBI development to determine the number of nearshore sampling stations needed per lake are found in Bacigalupi et al. (2021).

Table 2. Number of nearshore sites sampled based on lake size.

Lake Surface Area (acres)	Number of Sites
< 500	10
500–1,199	14
1,200–1,999	18
> 2,000	24

Once a lake is selected for IBI sampling, sampling sites must be generated if they do not exist. Points are generated prior to the sampling season and loaded into Fisheries Survey Module (FSM) by a DNR Fisheries GIS Specialist. Contact LBMA Program Supervisor if points are needed for a lake that does not have them.

A desktop review of site locations should be completed to ensure sampling stations are located in areas of the lake that are accessible by boat. If not, the DNR Fisheries GIS Specialist can regenerate points based on modified lake delineations.

Data Entry into Fisheries Survey Module (FSM)

A targeted survey should be created in FSM that will contain the nearshore survey components and associated fish data. For any repeat nearshore surveys conducted within the same year, separate targeted surveys with different survey ID dates should be created.

Required electrofishing and seining components should be added as needed while completing the nearshore survey. Only components that are sampled should be added. For example, if seining is not possible at a site due to reasons specified in the **Sampling Difficulties** section below, do not add a seining component for that sampling station. Add a crew note to the survey describing which stations were not seined and the conditions that prevented seining.

For each backpack electrofishing (i.e., EFB) component, ensure that the fields outlined in blue in Figure 1 are filled in at minimum and that all checkboxes are checked. Include a short description of the habitat sampled and site conditions in the crew notes. Other fields are optional but should also be filled in when possible, although many are only applicable to streams.

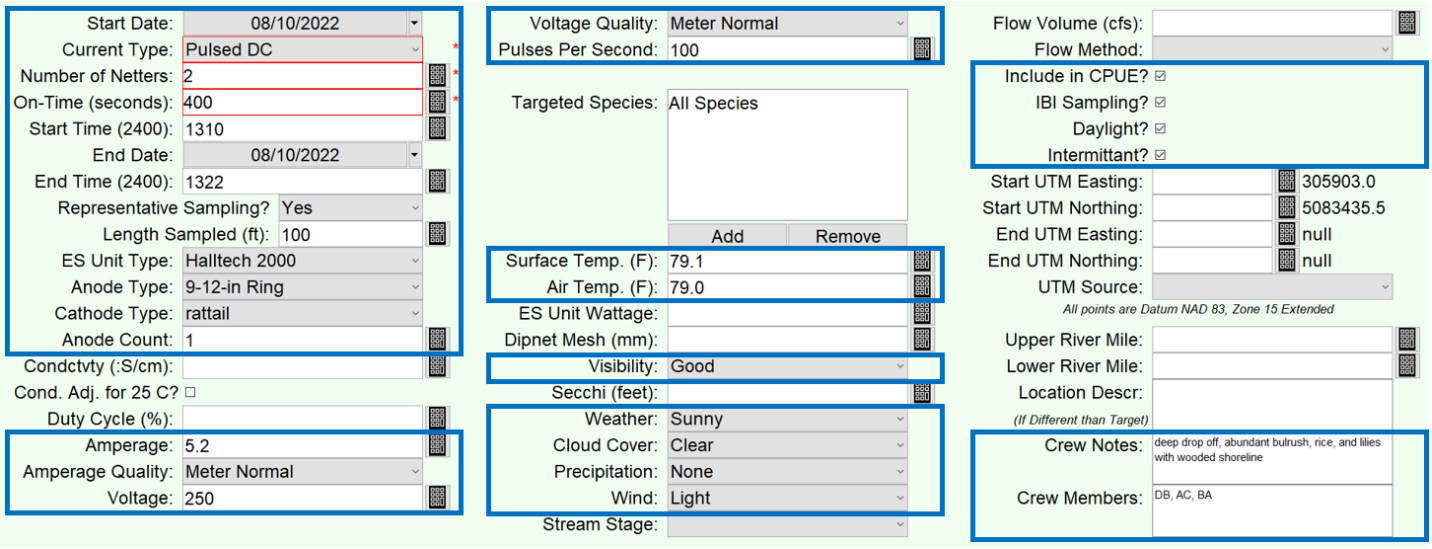

Figure 1. Example backpack electrofishing (EFB) component in Fisheries Survey Module (FSM), with IBI survey required fields outlined in blue.

For each seining component (i.e., S58 or S18), ensure that the fields outlined in blue in Figure 2 are filled in at minimum and that all checkboxes are checked. Record the appropriate substrate types and vegetation density at the station.

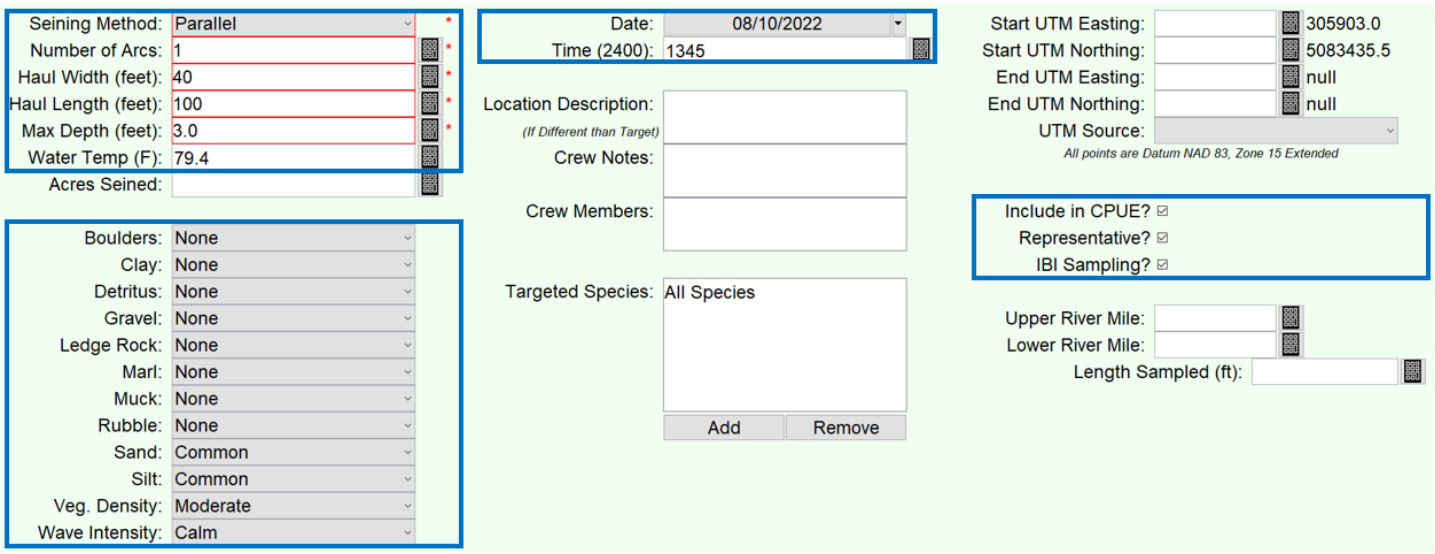

Figure 2. Example seining (S58 or S18) component in Fisheries Survey Module (FSM), with IBI survey required fields outlined in blue.

All fishes sampled in each nearshore gear type should be entered in the appropriate Unmeasured Fish table. Enter species name, total count, count of vouchered individuals, and count of individuals with external deformities, erosion, lesions, or tumors (DELTs). If individuals are young of the year (YOY), check the "YOY" checkbox. Do not count or enter information for YOY fish under 25 mm (approximately 1 inch).

If a site is moved (refer to **Sampling Difficulties** section below for examples of when appropriate to move a site), the starting GPS coordinates at the relocated site should be added into the gear component screen and a comment should be added in the crew notes. A location description for the relocated site can also be added. In order to retain the location for the relocated station for future surveys, the location coordinates should also be updated in the "Manage Target Station List" screen for the EFB, S18, and S58 components associated with that station number.

To increase repeatability during future surveys, photos can be taken of each site and uploaded into FSM. Individual station photos should be labeled with the station number, combined into one file, and added as a survey attachment in the Survey Detail screen. Individual photos can also be added to each EFB component as an attachment; however, exporting a combined file from the Survey Detail screen is easier and preferred. In either case, do not check the "Include in reports" box for these files.

Additional FSM data entry instructions not covered here can be found in the Manual of Instructions for Lake Survey (MNDNR 2017). For general lake survey support, contact the Lake Survey Program Coordinator.

Protocol for Sampling Fish

Nearshore sampling of fish should occur from approximately June 15–September 15, where survey repeatability has been demonstrated. The season may start later or end earlier if local weather conditions dictate. Where possible, prioritize IBI sampling for July or August and when nearshore surface water temperatures average 70°F or above.

Navigate to the sampling station, attempting to be within 100 feet of the site location according to the GPS, without missing unique habitats. If access to the site is impossible or extremely difficult, the site should be moved to the nearest location with similar habitat where sampling is possible (see Sampling Difficulties section below for more details). Although sites can me moved, it is important to sample difficult habitats even if needing to use a shorter or narrower seine haul or a boat-assisted seine—in many cases, unique fish species are sampled in these locations.

Before deploying any sampling gear, measure the site. This step can be omitted once all crew members are confident with estimating 100 feet. It is advised that site length is periodically verified throughout the sampling season. At the first site determine if seining or backpack electrofishing will be completed first. The type of sampling gear used first will alternate at each site.

The goal for the lake IBI is to obtain a repeatable, representative sample of the fish community in each lake. In terms of nearshore sampling, the "targeted" area for each station is approximately 100 feet along the shoreline and up to 50 feet lakeward. Sampleable lakeshore habitat does not often lend itself well to these constraints; therefore, modifications to the "targeted" area may be necessary. It might help to think of the nearshore sampling station as one unit of effort, where two types of equipment and various ways of deploying each can be used to effectively sample the station.

Backpack Electrofishing

The sampling station should first be inspected to determine if it can be safely electrofished via wading along the shoreline (e.g., reasonable footing, appropriate depth). If determined that the site cannot be sampled safely via wading, refer to the **Backpack Electrofishing from the Boat** section. If the site can be sampled safely, then proceed in the following manner.

First, determine which crew member will wear the backpack electrofishing unit (i.e., "operator") and which will net fishes (i.e., "netter"). The operator should enter the water without the backpack electrofishing unit. A netter that is still in the boat should assist the operator with putting on the backpack electrofishing unit, reducing the risk of submerging the unit. While the backpack electrofishing unit is still turned off, the netter can reset the timer and check the settings on the unit. Settings can be adjusted once electrofishing begins—let the fish response (i.e., if they are sufficiently stunned for netting) dictate whether the settings are appropriate. The operator and netter(s) should confirm they are wearing rubber or PVC gloves and polarized sunglasses prior to commencing electrofishing.

Once all safety precautions are taken, the operator can begin electrofishing. The operator should move away from the boat parallel to the shoreline and should move the anode in a sweeping motion. During this first pass, it is important to electrofish the area immediately adjacent to the shoreline since it is at times difficult to seine right up to the water's

edge. All fish should be netted and placed in a bucket. Once the far end of the station (i.e., 100 feet) is reached, the operator and netter(s) should turn around and walk back towards the boat. The location of the second pass should be slightly further from shore than the first, yet the sweeps from both passes should overlap slightly. The pace for each pass should be slightly slower than a regular walking pace. Intermittent electrofishing can be used to improve success. For example, if fish are moving ahead of the field, attempts can be made to corral them, or the anode can be removed from the water and quickly re-submerged near the fish and/or structure.

After both passes are completed, totaling 200 feet, the backpack electrofishing unit should be shut off and lifted from the operator's back by a crew member that is in the boat. All required fields outlined in Figure 1 should be entered in the EFB component in FSM at this time if not already completed. The time should be noted and entered accordingly. Similarly, "100" should be entered into the "Length Sampled (ft)" field if the full length of the station was electrofished. The fish caught should be identified, enumerated, and recorded, as outlined in the **Data Entry into Fisheries Survey Module (FSM)** section.

Seining

The sampling station should first be inspected to determine if it can be safely and effectively seined (e.g., reasonable footing, appropriate depth). If determined that the site cannot be sampled safely or effectively with a traditional seine haul, refer first to the **When a** site presents an atypical situation, try to find somewhere to sample within the site. Seining will generally yield a greater diversity of fishes than backpack electrofishing. Before moving or skipping a site, attempt to find a way to sample some portion or the entire site by backpack electrofishing, seining, or both. This is not an all-inclusive list of situations that will be encountered. Use professional judgment or contact LBMA Program staff and ask their professional opinion. Additional examples of difficult sampling situations and guidelines can also be found in **Appendix D**. Examples of Difficult Sampling Situations.

Site Difficulties section to ensure that an adequate number of sites are seined and then to the **Seining Difficulties** section for techniques that can be considered. If the site can be sampled safely and effectively with a traditional seine haul, then proceed in the following manner.

Seining should be completed following the parallel seining protocol in the Manual of Instructions for Lake Survey (MNDNR 2017) whenever conditions allow. Essentially, the seine should be extended into the lake on a line perpendicular to shore to the full length of the seine or as far from shore as water depth allows. The shallow end should remain at or near shore when conditions permit. The seine should be hauled parallel along the shore for the length of the station, at which time the outer end is swept in an arc toward the shoreline and the seine is pulled up to the shoreline and lifted out of the water. All required fields outlined in Figure 2 should be entered in the S58 or S18 component in FSM at this time if not already completed. The fish caught should be identified, enumerated, and recorded, as outlined in the **Data Entry into Fisheries Survey Module (FSM)** section. Refer to the **Seining Difficulties** section for guidance about what to do in an atypical or difficult seining situations (such as deep drop-offs or narrow boat channels).

Whenever possible, the 50-foot seine (i.e., S58) should be used and the full length of the station (i.e., 100 feet) should be sampled. The ends can be rolled over to shorten the seine if there are obstructions in the water or if deep water limits full deployment—note actual width deployed in FSM "Haul Width" field. If the site is very difficult and precludes seining with the 50-foot seine, the 15-foot seine (i.e., S18) should be used and the same amount of area (i.e., 50 feet or to deep water x 100 feet) should be sampled in multiple pulls if the site allows it (refer to the **Seining Difficulties** section for details). For instance, if there is woody habitat or a dock in the middle of a site, two or more pulls may be required to complete a site.

Sampling Difficulties

When a site presents an atypical situation, try to find somewhere to sample within the site. Seining will generally yield a greater diversity of fishes than backpack electrofishing. Before moving or skipping a site, attempt to find a way to sample some portion or the entire site by backpack electrofishing, seining, or both. This is not an all-inclusive list of situations that will be encountered. Use professional judgment or contact LBMA Program staff and ask their professional opinion. Additional examples of difficult sampling situations and guidelines can also be found in **Appendix D**. Examples of Difficult Sampling Situations.

Site Difficulties

Whenever possible, sites should not be moved, or seine hauls skipped. Sometimes the difficult sites can yield unique fish species that are not found in the rest of the lake. Effort should be taken to access and sample these sites, while still remaining legal and safe. However, if a site needs to be moved, it should be moved to the closest "sampleable" location with as similar characteristic to the original site as is practical. In some cases, this may be the outside edge of an emergent fringe.

Reasons to move a sampling station, skip a seine haul, or alter the standard sampling methods at a sampling station may include:

- Inaccessibility to the shoreline by either walking, boating, or push-poling.
    - If dense cattails, lilies, wild rice, or other aquatic vegetation are present, backpack electrofishing from the boat may be required. If not equipped to do so safely, a site can also be moved.
- Deep water immediately adjacent to shore.
    - If bog fringe, backpack electrofishing from the boat may be required. If not equipped to do so safely, a site can also be moved
    - Can consider parallel, boat-assisted seine when possible for one crew member to safely wade in water.
- High density of docks (e.g., marina) or beach.
    - Move the site to the nearest sampleable location.
- High winds/waves on shore.
    - Reduces efficiency of netting fish and presents possible footing danger.
    - Can be sampled once winds die down if situation allows.
- Animals or people in the water.
    - Can be sampled once animals or people are no longer in the water if situation allows.

Backpack Electrofishing from the Boat

Unlike seining, backpack electrofishing should occur at all sampling sites required for a lake of a given size (Table 2), using backpack electrofishing from the boat when needed. Note that an EFB component type should still be selected in FSM for this technique. Sampling sites may be moved if necessary, particularly to accommodate the minimum number of seine stations required for a lake. Nonetheless, backpack electrofishing from the boat can be used in situations where:

- Wading at a site would be dangerous (e.g., loose or slippery rocks, soft substrate, large trees in the water).
- Water depth at a site is too deep for wading.
- Any crew member has reservations about wading the site.

Due to nontraditional usage of the backpack electrofishing unit, modifications were made to assure all users' safety. If the decision is made to backpack electrofish from the boat, a remote kill switch must be connected to the backpack electrofishing unit. The boat driver should operate the remote kill switch and test its operation before beginning sampling.

To accomplish this type of sampling safely, the backpack should be secured in some way to the boat and the kill switch connected. All crew members in the boat should put on rubber or PVC gloves, including the person who pushes the boat along with either a push pole or the outboard (i.e., "driver"). The backpack operator should be located at the front of the boat and is responsible for the movements of the anode and cathode. The netter should be behind the backpack and operator (i.e., middle of the boat) and is responsible for setting up a bucket in an area where they can easily place the fish once collected. The driver should be at the back of the boat, moving the boat along with a push pole or the outboard (if vegetation and water clarity are not a factor). This task can be completed with only two crew members but should be done more slowly as it can be difficult for one person to operate both the backpack and the net.

Once crew members are in place, the operator should place the cathode and anode over the side of the boat, ensuring that the metal portion of the cathode is not touching the boat. The operator should then turn on the unit and indicate that they will begin electrofishing, doing so for a short period of time to ensure fish are sufficiently stunned. Once ready, the backpack operator and netter signal the driver to begin moving the boat forward. The main responsibilities of the driver are to ensure the boat moves as smoothly as possible while moving at a pace similar to a walking pace and to alert the operator and netter of any obstacles in the way, such as tree branches.

Because of the difficulties and inefficiencies associated with backpack electrofishing out of the boat, the length of the station should be doubled to 200 feet from the starting point. The driver can meander between depths while moving the boat along the shoreline. Once the boat has traveled 200 feet down the shoreline, the driver should turn the boat around and make another pass further from shore, such as on the outside edge of the vegetation, and towards the starting point. More commonly, if unable to travel back to the starting point because of site constraints, the length of the station can be extended such that 400 feet are sampled overall in one direction. Once electrofishing is completed, the operator should turn off the unit and bring the anode and cathode into the boat. The backpack electrofishing unit should then be released from the boat and placed in an area for transport. The time should be noted and entered accordingly. The distance traveled between the starting point and the furthest point sampled (e.g., 200 or 400 feet) should be entered into the "Length Sampled (ft)" field and a comment specifying that backpack electrofishing from the boat was used should be added to the "Crew Notes" field in FSM. The fish caught should be identified, enumerated, and recorded.

Seining Difficulties

Seining should be completed at as many sites as possible and at a minimum of 70% of the sample sites required for a lake of a given size (Table 2). Sampling stations may be moved if necessary to achieve this. However, seining even a very small area (e.g., 10 feet by 20 feet) or using a non-traditional approach (e.g., fixed pole, perpendicular, or boat-assisted seining) can often effectively sample species in difficult habitats. This will require some professional judgment by crew members. In some cases, the shoreline of the lake will be such that it will not be possible to meet these criteria, at which seining at the site may be skipped provided that at least half of the sample sites on the lake are seined. For sites where seining is skipped, a comment that seining was skipped and a justification/general description of sampling difficulties

should be added to the "Crew Notes" field in the EFB component for that station. If sampling Lake Class 1–19 lakes, disregard this paragraph and follow the protocols as described in **Appendix A**. Nearshore Sampling and Voucher Protocol Modification for Boreal Shield Lakes.

Dense Submerged or Floating-leaf Vegetation

Dense submerged or floating-leaf vegetation can limit effectiveness of a seine haul. In some instances, the 15-foot seine rather than the 50-foot seine can be used more effectively. Regardless of which seine is used, it should be deployed in the normal manner; however, when moving through the vegetation the lead line should be kept as taut as possible and the seine should be moved forward in quick, short bursts (i.e., referred to as ripping the seine) through the vegetation. It is very common that the seine will roll around the lead line. If this occurs there are several options:

- Pull multiple short seines through the site to limit the chance of the net rolling.
- Continue moving though the site and have a third crew member assist by periodically pulling the bag of the net to reduce the rolling.
- Once the seine starts rolling, both crew members grab the lead line, walk back away from each other, and lift rapidly so that fish remain trapped in the seine.

Once the seine is pulled to shore, large amounts of vegetation may be present in the net. If this occurs, the vegetation must be screened very carefully. It is very easy to miss fishes in vegetation. If necessary, 2–3 seine hauls should be completed if using the 15-foot seine to cover the entire station.

Dense Emergent Vegetation

Emergent vegetation, usually cattails and bulrush, tend to lift the lead line off the bottom. There are two options for seining in emergent vegetation:

- If the density of the vegetation is low, the seine may be "ripped" over the vegetation. This practice works better in very sparse cattail and moderately sparse bulrush.
- If the emergent vegetation is too dense, it may be possible to either find open space in the vegetation or sample on the outside of the vegetation. In some cases, there is a gap next to shore, near a dock, or the water is shallow enough to allow seining on the outside edge of the emergent vegetation.

If depth and vegetation are confounding factors, seine using either the push-pole or boat motor to extend the seine from the shore or edge of the vegetation and sweep around (i.e., fixed pole seining).

Coarse Woody Habitat (CWH)

CWH can get caught in, snag, or rip a seine, and the risk is largely dependent on the amount and diameter present at the site. If there is a small amount and small diameter CWH that will not snag or rip the net, seine the site as normal. However, if it is likely that amount and diameter of the CWH will snag and/or rip the net there are several options:

- Have a third crew member assist by guiding the net to avoid being snagged and untangling the net if it does get caught.
- Pull multiple seine hauls between CWH.
- Attempt to find an area, even a small area, where a seine haul can be completed.

Rocky Shorelines

Rocks can get caught in, snag, or rip a seine, and the risk is largely dependent on the amount and size present at the site. Depending on rock size, seining can be completed using one of the following options:

- If the rocks are smaller than softballs, proceed to seine in a normal fashion. However, it is common to pick up a rock or two while seining.
- If the rocks are between the size of softballs and basketballs, attempt to seine as close to normal as possible. However, it will be more common to get snagged on rocks. Have the third crew member assist with unhooking the net from obstacles.
- If the rocks are larger than basketball size, seining efficiency decreases as rock size increases. If possible, find a stretch within the site that has smaller rocks and seine that area. If not, seining may not be possible.

Steep Shorelines

Steep shorelines might not be possible to seine using traditional methods because only one of the two crew members required to pull the seine can effectively wade in the water before it becomes too deep. In these cases, the crew can utilize a parallel, boat-assisted seining technique. This technique is similar to the parallel seining protocol; however, the boat itself serves as the crew member on the deep side of the seine. The float line on the deep end of the seine can be attached directly to the bow using a carabiner. The lead line can be attached by a carabiner to an anchor that is connected to the bow of the boat by a short (i.e., 4 feet) rope. With one crew member in the water at the shoreline and holding the shallow end of the seine, the boat operator should move the boat perpendicular to shore to the full length of the seine. The boat operator and crew member that is wading along the shoreline will move the seine parallel to the shoreline until the length of the station is reached, at which point the boat operator will position the boat such that the crew member in the water can detach the deep end of the seine from the boat. The boat operator will then park the boat along the shoreline and assist the other crew member with pulling in the seine and lifting it out of the water. Additional documentation for this technique, including a video demonstration, can be obtained by contacting the LBMA Program Supervisor.

Large Sample Sizes/Subsampling

Subsampling is not permitted. All fish must be identified and sorted into separate lots/buckets at each station. In most cases each fish will be counted. For very large catches (i.e., several hundred to several thousand individuals), fish should be sorted to species and then the count estimated volumetrically with a small net, plastic container, or similar.

Protocol for Collecting and Preserving Voucher Specimens

Preparing Voucher Labels, Bottles, and Bags

Labels should be included with each voucher bottle and must contain the following information: Full DOW (00-0000-00), Lake Name, County, State, Survey Date (e.g., 25 June 2022), Collector, Station Number, Gear(s) Used, and Bottle __ of __ (for the survey). Refer to **Appendix B**. Seining and Electrofishing Field Data Sheet and Voucher Bottle Labels for an example of a voucher bottle label. Excel versions are also available—contact LBMA Program Supervisor if needed.

- Labels should be printed on Resistall paper using LaserJet ink, as labels will remain with specimens for years. Any writing on the labels should be done in pencil.

- One label should be attached to the outside of each voucher bottle using clear packaging tape and another identical one should be inserted into the bottle. Any old labels or writing should be removed from the bottle.
- Each bottle should be labeled as containing 10% formalin. Preprinted formalin labels are available for purchase at several websites.
- A separate bottle must be used for fish sampled at each station (i.e., fish sampled at multiple stations cannot be combined into the same voucher bottle). For the most part fish can be loose in the bottle instead of bagged as discussed below.
- For preservation purposes and the safety of those doing the voucher verification, bags should only be used to separate unknown fish or fish that are suspected as misidentified. The preferred bag is clam boil or similar loose mesh bags due to formalin retention and formalin exposure. Do not purchase additional fine mesh muslin bags. Do not use whirl-packs. Muslin or cotton bags should be immersed in water prior to adding specimens, as some species may lose their scales more easily in a dry bag.
- In bottles that are relatively full of specimens, it is important that sufficient formalin be added to ensure proper fixation. Do not over fill bottles with fish. If one bottle is insufficient, a second bottle can be used for the station. However, specimens should be consolidated into a larger bottle before sending on for verification if possible.

Voucher Requirements

Fish should be vouchered using the following strategies and corresponding to the number required for each lake or station, as indicated in **Appendix C**. List of Fish Species and Voucher Requirements.

- Live or freshly dead adult fish with intact fins should be selected when available for vouchering. Representative specimens preserved in good condition are much easier to identify. Fish under 25 mm (approximately 1 inch) should not be vouchered or included in counts.
- A minimum of 2 individuals of each fish species in category A (e.g., most game fish and other easily identifiable fish) should be vouchered per lake (**Appendix C**. List of Fish Species and Voucher Requirements). Put these fish into the bottle for the appropriate station rather than a separate bottle.
- A minimum of 5 individuals of each fish species in category B (e.g., bullheads, sunfish, darters, and minnows) should be vouchered per station (**Appendix C**. List of Fish Species and Voucher Requirements). More than 5 individuals can be vouchered per station if uncertain about identification since a larger sample size will better facilitate corrections, if necessary. Any species not listed in category A or B should also be vouchered at 5 or more individuals per station.
- Preserve any fishes when any of the following criteria are met: species identification is uncertain, a species not previously documented in the lake has been sampled, or collection results in range expansion of the species.
- If a fish is too large to voucher and is novel to the survey, several photographs with identifying features can be taken instead. This is especially important if it is a new species for the lake or would result in range expansion of the species. Name the file with the following convention [Year_SurveyDate_DOW_Station_Collector_Species], such as 2012_April16_18000100_EFB1_JBacigalupi_Bluegill. Contact LBMA Program Supervisor for location on I:Drive to upload photos to.

Currently, voucher specimens are only required to be taken during nearshore sampling. However, if identification of fish encountered during gill net or trap net sampling is uncertain or if fish encountered in those gears would result in a range expansion, photograph and catalog as above.

References

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

MNDNR (Minnesota Department of Natural Resources). 2017. Manual of instructions for lake survey. MNDNR Special Publication 180, St. Paul, Minnesota.

MNDNR. 2020. Section of Fisheries safety manual. MNDNR, St. Paul, Minnesota.

Appendix A. Nearshore Sampling and Voucher Protocol Modification for Boreal Shield Lakes

The following techniques should be used when sampling Boreal Shield lakes (Schupp Lake Classes 1–19).

Nearshore Sampling

Each established nearshore sampling station should be sampled with the backpack electrofishing unit and 1/8-inch mesh mini-fyke nets (TMF) when possible. Field crews should also seine at least 70% of the lake's required number of nearshore stations (Table 2), rounded up to the next whole site. Where needed to meet this target, establish new stand-alone seine stations that are not associated with a previously established station. Select sites that represent as much habitat diversity as practical. Backpack electrofishing and seining methods are outlined in the **Backpack Electrofishing** and **Seining** sections above. Mini-fyke netting methods are outlined in the Manual of Instructions for Lake Survey (MNDNR 2017).

TMF and seine station numbers should correspond with the associated EFB station number. For example, at EFB1, use TMF201 for the mini-fyke station number and S181 or S581 for the seine station number, depending on the gear used. The TMF200 series distinguishes these stations from those previously established by Area Fisheries offices for other purposes. Number stand-alone seine stations sequentially beginning at 301, using the appropriate S18 or S58 gear code (e.g., S18301 or S58301). The 300 series distinguishes stand-alone seine stations from those associated with an EFB station. When possible, the established nearshore and 300 series seine stations should be used in repeat surveys.

Voucher Specimens

At each established nearshore station, combine voucher specimens from backpack electrofishing, seining, and mini-fyke netting into the same station-specific bottle. Follow the voucher requirements in **Protocol for Collecting and Preserving Voucher Specimens**, applying station-level minimums to the combined catch across all three gears. Include all associated station numbers and gears used on the voucher labels.

Voucher specimens from each stand-alone seine station (300 series) must be kept in a separate station-specific bottle and meet the station-level voucher requirements independently. Do not combine specimens from different stations.

Appendix B. Seining and Electrofishing Field Data Sheet and Voucher Bottle Labels

(Forms begin on the next page. Editable Excel forms available for voucher bottle labels—contact LBMA Program Supervisor)

Lake Name _____ Survey ID Date _____ Page _____

DOW _____ Crew Members _____ Crew Notes _____

	EFB Station		S Station		EFB Station		S Station	
	Date		S Type	[S58][S18]	Date		S Type	[S58][S18]
	Start Time		Method	[Pa][Fi][Pe]	Start Time		Method	[Pa][Fi][Pe]
	End Time		Width (ft)		End Time		Width (ft)	
	On-Time		Length (ft)		On-Time		Length (ft)	
	Length (ft)		Depth (ft)		Length (ft)		Depth (ft)	
	Amperage		Surface Temp (F)		Amperage		Surface Temp (F)	
	Voltage		Boulders	[A][C][R][N]	Voltage		Boulders	[A][C][R][N]
	Frequency		Clay	[A][C][R][N]	Frequency		Clay	[A][C][R][N]
	Surface Temp (F)		Detritus	[A][C][R][N]	Surface Temp (F)		Detritus	[A][C][R][N]
	Air Temp (F)		Gravel	[A][C][R][N]	Air Temp (F)		Gravel	[A][C][R][N]
	Visibility	[G][M][P]	Ledge Rock	[A][C][R][N]	Visibility	[G][M][P]	Ledge Rock	[A][C][R][N]
	Weather		Marl	[A][C][R][N]	Weather		Marl	[A][C][R][N]
	Cloud Cover		Muck	[A][C][R][N]	Cloud Cover		Muck	[A][C][R][N]
	Precipitation		Rubble	[A][C][R][N]	Precipitation		Rubble	[A][C][R][N]
	Wind		Sand	[A][C][R][N]	Wind		Sand	[A][C][R][N]
	Crew Notes		Silt	[A][C][R][N]	Crew Notes		Silt	[A][C][R][N]
			Veg Density	[D][M][L][N]			Veg Density	[D][M][L][N]
			Wave Int	[C][L][M][S]			Wave Int	[C][L][M][S]
			Date				Date	
			Time				Time	

S Type: [S58] 50' and 1/8" mesh, [S18] 15' and 1/8" mesh Seining Method: [Pa]rallel, [Fi]xed Pole, [Pe]rpindicular Substrate: [A]bundant, [C]ommon, [R]are, [N]one

Vegetation: [D]ense, [M]oderate, [L]ight, [N]one Wave Int: [C]alm, [L]ight, [M]oderate, [S]trong Visibility: [G]ood, [M]oderate, [P]oor

Species	Count	Voucher	YOY	DELTs	Count	Voucher	YOY	DELTs	Count	Voucher	YOY	DELTs	Count	Voucher	YOY	DELTs
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Entered_____ Entered_____ Entered_____ Entered _____

Collector: _____ DOW #: _____ Lake Name: _____ Date: _____ Station #: _____ Total Jars: Contains 10% Formalin	Collector: _____ DOW #: _____ Lake Name: _____ Date: _____ Station #: _____ Total Jars: Contains 10% Formalin	Collector: _____ DOW #: _____ Lake Name: _____ Date: _____ Station #: _____ Total Jars: Contains 10% Formalin
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Appendix C. List of Fish Species and Voucher Requirements

Common Name	Species	Category	# Vouchers Required
Banded Killifish	*Fundulus diaphanus*	A	2 per LAKE
Bigmouth Buffalo	*Ictiobus cyprinellus*	A	2 per LAKE
Black Crappie	*Pomoxis nigromaculatus*	A	2 per LAKE
Bowfin	*Amia ocellicauda*	A	2 per LAKE
Brook Silverside	*Labidesthes sicculus*	A	2 per LAKE
Brook Stickleback	*Culaea inconstans*	A	2 per LAKE
Brook Trout	*Salvelinus fontinalis*	A	2 per LAKE
Brown Trout	*Salmo trutta*	A	2 per LAKE
Burbot	*Lota lota*	A	2 per LAKE
Central Mudminnow	*Umbra limi*	A	2 per LAKE
Central Stoneroller	*Campostoma anomalum pullum*	A	2 per LAKE
Channel Catfish	*Ictalurus punctatus*	A	2 per LAKE
Chestnut Lamprey	*Ichthyomyzon castaneus*	A	2 per LAKE
Cisco	*Coregonus artedi*	A	2 per LAKE
Common Carp	*Cyprinus carpio*	A	2 per LAKE
Flathead Catfish	*Pylodictis olivaris*	A	2 per LAKE
Freshwater Drum	*Aplodinotus grunniens*	A	2 per LAKE
Gizzard Shad	*Dorosoma cepedianum*	A	2 per LAKE
Lake Sturgeon	*Acipenser fulvescens*	A	2 per LAKE
Lake Trout	*Salvelinus namaycush namaycush*	A	2 per LAKE
Lake Whitefish	*Coregonus clupeaformis*	A	2 per LAKE
Largemouth Bass	*Micropterus nigricans*	A	2 per LAKE
Logperch	*Percina caprodes*	A	2 per LAKE
Longnose Gar	*Lepisosteus osseus*	A	2 per LAKE
Longnose Sucker	*Catostomus catostomus*	A	2 per LAKE
Muskellunge	*Esox masquinongy*	A	2 per LAKE
Northern Hog Sucker	*Hypentelium nigricans*	A	2 per LAKE
Northern Pike	*Esox lucius*	A	2 per LAKE
Quillback	*Carpiodes cyprinus*	A	2 per LAKE
Rainbow Smelt	*Osmerus mordax*	A	2 per LAKE
Rainbow Trout	*Oncorhynchus mykiss*	A	2 per LAKE
River Carpsucker	*Carpiodes carpio*	A	2 per LAKE
Rock Bass	*Ambloplites rupestris*	A	2 per LAKE
Sauger	*Sander canadensis*	A	2 per LAKE
Shortnose Gar	*Lepisosteus platostomus*	A	2 per LAKE
Smallmouth Bass	*Micropterus dolomieu*	A	2 per LAKE
Smallmouth Buffalo	*Ictiobus bubalus*	A	2 per LAKE
Splake	*Salvelinus fontinalis x S. namaycush*	A	2 per LAKE
Tiger Muskellunge	*Esox Lucius x E. masquinongy*	A	2 per LAKE
Trout-perch	*Percopsis omiscomaycus*	A	2 per LAKE
Walleye	*Sander vitreus*	A	2 per LAKE
White Bass	*Morone chrysops*	A	2 per LAKE
White Crappie	*Pomoxis annularis*	A	2 per LAKE
White Sucker	*Catostomus commersonii*	A	2 per LAKE
Yellow Bass	*Morone mississippiensis*	A	2 per LAKE
Yellow Perch	*Perca flavescens*	A	2 per LAKE
Bigmouth Shiner	*Ericymba dorsalis*	B	5 per STATION

Common Name	Species	Category	# Vouchers Required
Black Bullhead	*Ameiurus melas*	B	5 per STATION
Blackchin Shiner	*Miniellus heterodon*	B	5 per STATION
Blacknose Dace	*Rhinichthys obtusus*	B	5 per STATION
Blacknose Shiner	*Notropis heterolepis*	B	5 per STATION
Blackside Darter	*Percina maculata*	B	5 per STATION
Bluegill	*Lepomis macrochirus*	B	5 per STATION
Bluntnose Minnow	*Pimephales notatus*	B	5 per STATION
Brassy Minnow	*Hybognathus hankinsoni*	B	5 per STATION
Brown Bullhead	*Ameiurus nebulosus*	B	5 per STATION
Common Shiner	*Luxilus cornutus*	B	5 per STATION
Creek Chub	*Semotilus atromaculatus*	B	5 per STATION
Emerald Shiner	*Notropis atherinoides*	B	5 per STATION
Fantail Darter	*Etheostoma flabellare*	B	5 per STATION
Fathead Minnow	*Pimephales promelas*	B	5 per STATION
Finescale Dace	*Chrosomus neogaeus*	B	5 per STATION
Goldfish	*Carassius auratus*	B	5 per STATOIN
Golden Redhorse	*Moxostoma erythrurum*	B	5 per STATION
Golden Shiner	*Notemigonus crysoleucas*	B	5 per STATION
Greater Redhorse	*Moxostoma valenciennesi*	B	5 per STATION
Green Sunfish	*Lepomis cyanellus*	B	5 per STATION
Hornyhead Chub	*Nocomis biguttatus*	B	5 per STATION
Hybrid Sunfish	*Lepomis sp. X Lepomis sp.*	B	5 per STATION
Iowa Darter	*Etheostoma exile*	B	5 per STATION
Johnny Darter	*Etheostoma nigrum*	B	5 per STATION
Least Darter	*Etheostoma microperca*	B	5 per STATION
Longnose Dace	*Rhinichthys cataractae*	B	5 per STATION
Mimic Shiner	*Paranotropis volucellus*	B	5 per STATION
Mottled Sculpin	*Cottus bairdii*	B	5 per STATION
Northern Redbelly Dace	*Chrosomus eos*	B	5 per STATION
Northern Sunfish	*Lepomis peltastes*	B	5 per STATION
Orangespotted Sunfish	*Lepomis humilis*	B	5 per STATION
Pearl Dace	*Margariscus nachtriebi*	B	5 per STATION
Pugnose Minnow	*Opsopoeodus emiliae*	B	5 per STATION
Pugnose Shiner	*Miniellus anogenus*	B	5 per STATION
Pumpkinseed	*Lepomis gibbosus*	B	5 per STATION
Rainbow Darter	*Etheostoma caeruleum*	B	5 per STATION
River Redhorse	*Moxostoma carinatum*	B	5 per STATION
Sand Shiner	*Miniellus stramineus*	B	5 per STATION
Shorthead Redhorse	*Moxostoma macrolepidotum*	B	5 per STATION
Silver Redhorse	*Moxostoma anisurum*	B	5 per STATION
Slenderhead Darter	*Percina phoxocephala*	B	5 per STATION
Slimy Sculpin	*Cottus cognatus*	B	5 per STATION
Spotfin Shiner	*Cyprinella spiloptera*	B	5 per STATION
Spottail Shiner	*Hudsonius hudsonius*	B	5 per STATION
Stonecat	*Noturus flavus*	B	5 per STATION
Tadpole Madtom	*Noturus gyrinus*	B	5 per STATION
Weed Shiner	*Alburnops texanus*	B	5 per STATION
Yellow Bullhead	*Ameiurus natalis*	B	5 per STATION

Appendix D. Examples of Difficult Sampling Situations

Difficult sampling situations are routinely encountered when completing nearshore fish surveys. The examples and strategies outlined below can be used as general guidelines when encountering difficult sampling situations, although the list is not intended to be exhaustive or prescriptive in nature.

	**Sandy substrate and high water clarity** Seining with a 50-foot seine was completed along the shoreline as normal. Backpack electrofishing was also completed but was challenging due to fish avoidance. Intermittent electrofishing was used to improve success. As fish moved ahead of the crew and electrical field, attempts were made to corral them, and the anode was removed from the water and quickly re-submerged near the fish and/or structure.
	**Excessive algae or turbidity** Seining with a 50-foot seine was completed along the shoreline as normal. Backpack electrofishing was also completed but was challenging due to limited visibility to dip net fish, particularly benthic species that tended to roll and stay near the bottom. Holding the anode just below the surface helped to pull fish higher into the water column for dip netting.
	**Heavily vegetated bay** A large expanse of aquatic vegetation prevented motoring or push-poling to the sampling station. Because achieving greater than 70% of seine hauls on the lake was possible, seining was skipped and backpack electrofishing from the boat was used for 400 feet along the edge of the vegetation, perpendicular to where the sampling station was located on shore. If achieving greater than 70% of seine hauls on the lake would have been challenging, the sampling station could have been moved to the nearest location with similar habitat where sampling with both gears was possible.

	**Bog with floating-leaf vegetation** Seining and backpack electrofishing via wading were not possible due to soft sediments, water depth, and a steep drop-off. Backpack electrofishing from the boat was completed and fixed-pole seining was utilized because the floating-leaf vegetation was rather sparse and the shoreline dropped off quickly. To fixed-pole seine, one crew member stood on the bog edge, one crew member used the push-pole to maneuver the boat in an arc (the boat motor could also be used in some situations), and the third crew member ensured the lead line remained below the water surface and the seine did not roll.
	**Sparse floating-leaf vegetation** Backpack electrofishing was completed along the shoreline as normal. Three 15-foot seine hauls were completed. Each was ripped through the vegetation perpendicular to shore, starting on the lakeward side where depth and substrate allowed. Fish captured in each seine haul were emptied into a single bucket that was carried by a third crew member, which reduced the need to wade back and forth to the boat multiple times.
	**Mixed emergent and floating-leaf vegetation** Backpack electrofishing via wading was not possible due to risk of backpack submersion, as the site was moderately deep. Backpack electrofishing from the boat was utilized along the outer edge of the vegetation, extending the distance sampled to 400 feet away from the starting point. Although too deep to safely backpack electrofish via wading, seining was still possible, and the 15-foot seine was used to sample a small opening in the vegetation (approximately 15 feet by 20 feet).

	**Moderate hardstem bulrush and sparse floating-leaf vegetation** Backpack electrofishing was completed along the shoreline as normal. Moderate hardstem bulrush would have rolled the 50-foot seine or limited seine effectiveness across much of the sampling station; however, a 15-foot seine was ripped through the area of sparse lilies between stands of hardstem bulrush.
	**Hardstem bulrush with shallow sandy substrate** Backpack electrofishing was completed along the shoreline as normal. Dense hardstem bulrush extending to a steep shoreline break resulted in skipping the seine haul at this station, as the seine would have rolled or been pushed out of the water completely. If achieving 70% or more seine hauls on the lake would have been challenging, the sampling station could have been moved to the nearest location with similar habitat where sampling with both gears was possible. Further, small gaps or openings on the inside edge of the hardstem bulrush are occasionally present within similar stations and can be sampled with a 15-foot seine.
	**Dense stands of cattail and hardstem bulrush with sandy substrate** Backpack electrofishing was completed along the shoreline as normal. Water was shallow enough at the outside edge of the hardstem bulrush stand to facilitate using the 50-foot seine; however, the full width of the seine was not utilized due to increasing depth. This resulted in some slack in the seine. If the depth were to have increased too rapidly along the edge to facilitate two crew members and a reasonable seine width, a parallel, boat-assisted seine haul could have been completed instead.

	**Coarse woody habitat and sparse floating-leaf vegetation** Backpack electrofishing was completed along the shoreline as normal. Two 15-foot seine hauls were completed in openings in the floating-leaf vegetation where coarse woody habitat was not as abundant. Fish captured in each seine haul were emptied into a single bucket that was carried by a third crew member, who also assisted with freeing the seine from snags as needed.
	**Coarse woody habitat with deep water** Seining and backpack electrofishing via wading were not possible due to abundant coarse woody habitat, water depth, and a steep drop-off. Seining was skipped because achieving greater than 70% of seine hauls on the lake was possible. If achieving greater than 70% of seine hauls on the lake would have been challenging, the sampling station could have been moved to the nearest location with similar habitat where sampling with both gears was possible. Backpack electrofishing from the boat was completed along 200 feet of shoreline among the coarse woody habitat and back to the starting point among the submerged vegetation just beyond the coarse woody habitat.
	**Rocky shoreline** Backpack electrofishing was completed along the shoreline as normal. The 50-foot seine was utilized, with a third crew member following the seine to free it from rock snags as needed.

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11/23/2026

MESERB
Minnesota Environmental Science and Economic Review Board
Using science and economics to improve environmental regulations

November 23, 2026

VIA CAH eCOMMENTS

The Honorable Suzanne Todnem
Administrative Law Judge
Court of Administrative Hearings
600 North Robert Street
P.O. Box 64620
Saint Paul, MN 55164-0620

RE: Post-Hearing Comments on Proposed Amendments to Minnesota Rules Chapter 7050 Governing Water Quality Standards for Lake Aquatic Life and Recreation; Revisor ID No. R-04740; CAH Docket No. 23-9003-39503

Dear Judge Todnem:

The Minnesota Environmental Science and Economic Review Board ("MESERB") is a joint powers organization of more than 60 cities, sanitary districts, and public utilities commissions that own and operate wastewater treatment facilities and hold NPDES/SDS permits. MESERB submitted prehearing comments and testified at the November 2, 2026 hearing.[1] We thank the Minnesota Pollution Control Agency ("MPCA" or "Agency") for its written responses to our prehearing questions.[2]

I. MATTERS RAISED IN PREHEARING COMMENTS AND TESTIMONY

A. The rule adds drinking water designations to 346 lakes without review.

The Agency confirmed that 346 lakes will move from Class 2B to Class 2A, carrying the Class 1B designation with them. It also confirmed that it "has not specifically reviewed these lakes for domestic consumption uses because that task is outside the scope of this rule."[3] The SONAR likewise describes the rule as making no change to "any use class other than Class 2."[4] That description does not match the rule's effect. The rule itself triggers the new Class 1B designation and, with it, new standards for sulfate, total dissolved solids, fluoride, nitrate plus nitrite, and several metals.[5] Those standards bind permitted discharges whether or not anyone drinks the water, and the record contains no finding that any of these lakes is, or could be, a drinking water source. Their application to these 346 lakes has not been shown to be needed or reasonable.

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[1] Letter from MESERB to Hon. Suzanne Todnem (Oct. 8, 2026) [hereinafter "Prehearing Comments"]; Public Hearing (Nov. 2, 2026) (testimony of Cooper Silburn on behalf of MESERB).
[2] MPCA, Response to Pre-Hearing Comments (Hearing Ex. I-2) (wq-rule4-27i) [hereinafter "MPCA Responses"].
[3] MPCA Responses, Resp. 6.
[4] MPCA, Statement of Need and Reasonableness, Proposed Amendments to Minn. R. ch. 7050 (Aug. 2026) (wq-rule4-27d) [hereinafter "SONAR"], at 13 & n.3.
[5] SONAR at 51, 56, 58.

MESERB asks the Agency to reconcile this discrepancy and list each water that will be designated Class 1 for the first time. Because Minn. R. 7050.0420 applies Class 1B to Class 2A waters unless otherwise listed, the Agency can address this in the use tables it is adopting: it should either evaluate the Class 1 use for each affected lake or specify that those lakes are not designated Class 1B until that review is done.

B. The record does not show that ammonia was evaluated or that wastewater impacts will be small.

MESERB asked whether the Agency evaluated the effect of new and more stringent standards for ammonia, nitrate, sulfate, and total dissolved solids on wastewater facilities.[6] The Agency responded that it "reviewed all parameters that would be new or more stringent."[7] The SONAR does not reflect that for ammonia. MPCA acknowledges that a Class 2A designation makes ammonia standards more stringent. Under Minn. R. 7050.0222, the chronic un-ionized ammonia standard drops from 40 µg/L to 16 µg/L.[8] However, its list of parameters screened for the coldwater designations names six Class 2A toxics, the Class 1B parameters, and TDO3, phosphorus, and chlorophyll-a. Ammonia is not among them.[9] Ammonia limits are among the costliest upgrades for small mechanical and pond systems. MESERB asks the Agency to state whether ammonia was screened and, if so, to place that analysis in the record.

The cost conclusion has a similar issue. Minnesota law requires the SONAR to describe the probable costs of compliance, including costs to local governments.[10] The SONAR states that no specific costs could be determined and that the modeling needed to decide whether a discharge causes or contributes to an impairment was "not feasible."[11] It nonetheless concludes that wastewater impacts "are not expected to be large or widespread," while flagging phosphorus discharges above Lake Bemidji and Lake Osakis as possibly needing tighter limits.[12] It also relies on site-specific standards to moderate impacts, though it acknowledges that, at least for Lake Bemidji, "additional data are needed" before those standards could be developed.[13] An analysis that could not determine which facilities will be affected cannot also support a finding that the effects on them will be small. The Agency should explain the basis for that finding and describe how the site-specific process will work, who will lead it, and who will bear its cost.

II. TECHNICAL BASIS FOR THE PROPOSED STANDARDS

MESERB's review of the materials supporting the rule found several choices that drive the proposed numbers but are not supported in the record.

A. Northern lake eutrophication standards.

1. <u>Baseline subtraction.</u> Even at very low chlorophyll-a (below 5 µg/L), the models predicted some failure of macrophyte goals, likely from stressors other than enrichment. The Agency

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[6] Prehearing Comments at 2.
[7] MPCA Responses, Resp. 5.
[8] SONAR at 35, 56; Minn. R. 7050.0222, subps. 2, 4.
[9] SONAR at 51.
[10] Minn. Stat. § 14.131 (5).
[11] SONAR at 52–53.
[12] *Id.* at 55, 58–59.
[13] *Id.* at 52, 58–59.

subtracted that initial exceedance rate, so the model starts at zero.[14] The result is that any increase above the lowest observed chlorophyll-a is presumed to cause impairment. Where does the record show that chlorophyll-a has a continuous adverse effect, rather than a threshold below which no adverse effect occurs?

2. The 10 percent exceedance rate. The report calls a 10 percent exceedance rate "reasonable and practical" but provides no data showing it is necessary.[15] For the fish model in polymictic lakes, the lowest chlorophyll-a in the dataset was 2 µg/L, and at that value the model estimated a 15.6 percent exceedance rate, already above the 10 percent target.[16] What data show that the effect of these other stressors is not significantly higher than 15.6 percent at higher chlorophyll-a concentrations?

3. Modeled versus observed scores. The models estimated exceedance rates of 6.8 percent for macrophytes and 15.6 percent for fish in polymictic lakes at the lowest chlorophyll-a levels in the data, and the Agency attributed those rates to factors other than enrichment. The record does not compare those modeled rates with the share of lakes actually falling below their biological goals at low chlorophyll-a, as shown in Figures 23 and 28.[17] MESERB asks the Agency to provide graphs plotting the modeled relative index scores against the observed data in Figures 23 and 28, and to compare each model's predicted exceedance rate with the observed share of lakes below threshold at low chlorophyll-a.

4. Percentile choices. Phosphorus and Secchi depth criteria were set from 90th and 10th percentile quantile regressions.[18] The 90th percentile ties phosphorus to the lakes that grow the most algae per unit of phosphorus, which helps drive the northern dimictic phosphorus standard down from 30 to 20 µg/L.[19] Why were these percentiles chosen, and what would the standards be under others?

B. Coldwater lake standards.

1. Habitat without fish. The report states that the largest error in predicting coldwater fish from oxythermal habitat came from "many lakes with apparently suitable oxythermal habitat which do not support coldwater fishes," especially lake whitefish and cisco.[20] That suggests the analysis is missing a significant factor for those species. The Agency states that each new coldwater lake was reviewed with the Department of Natural Resources, but the lake-specific data are not in the record and should be.[21]

2. Chlorophyll-a and causation. The report treats the decline in coldwater fish occurrence with rising chlorophyll-a as evidence of harm, which presumes a cause-and-effect relationship

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[14] MPCA, Development of Eutrophication Standards for Northern Lakes in Minnesota (2025) (wq-bsm4-05) (SONAR Ex. S-3) [hereinafter "Ex. S-3"], at 35 & fig. 22.
[15] Ex. S-3 at 36; *see also id.* at 40, 43.
[16] *Id.* at 40.
[17] *Id.* at 35, 40 & figs. 23, 28.
[18] *Id.* at 49.
[19] SONAR at 51.
[20] MPCA & MNDNR, Development of Water Quality Standards to Protect Coldwater Lake Habitats in Minnesota (December 2025) (SONAR Ex. S-4) [hereinafter "Ex. S-4"], at 26.
[21] MPCA Responses, Resp. 9.

that has not been shown.[22] The report concedes that chlorophyll-a predicted fish presence worse than oxythermal habitat did, that it could not explain why many lakes with good chlorophyll-a lack cisco or lake whitefish, and that the criteria "may need to be modified for individual lakes."[23] The SONAR adds that cisco have persisted in Lake Osakis despite chlorophyll-a above the proposed standard.[24] More research is needed, and phosphorus and chlorophyll-a criteria for cisco and lake whitefish are premature.

3. The 95 percent extirpation value. Chlorophyll-a thresholds of 12, 5, and 3 µg/L for cisco, lake whitefish, and lake trout were set at 95 percent extirpation values.[25] How did the Agency decide that 95 percent is the appropriate value for criteria development? MESERB also asks the Agency to make the data used to derive these criteria available in a format the public can readily review.

4. Percentile choices. As with the northern standards, phosphorus and Secchi depth were derived from 90th and 10th percentile regressions.[26] How did the Agency decide these percentiles, rather than others, were appropriate?

III. REQUESTED ACTION

MESERB respectfully asks the Administrative Law Judge to (1) find that the Agency has not shown the need and reasonableness of applying Class 1B standards to the 346 newly designated Class 2A lakes, unless it evaluates that use or excludes it in the use tables; (2) require the Agency to state whether ammonia was screened and justify the basis for its conclusion that wastewater costs will be small; and (3) require the Agency to answer the questions in Part II and make the underlying data and requested graphs available before adopting the thresholds that depend on them.

Thank you for considering these comments. MESERB values the Agency's work and its commitment to sound science, and we look forward to its post-hearing response.

Sincerely,

MINNESOTA ENVIRONMENTAL SCIENCE AND ECONOMIC REVIEW BOARD



Scott Gilbertson
MESERB President
Executive Director, Alexandria Lake Area Sanitary District

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[22] Ex. S-4 at 28.
[23] *Id.* at 29, 31.
[24] SONAR at 59.
[25] Ex. S-4 at 28.
[26] *Id.* at 33.