Sustaining Lakes in a Changing Environment – SLICE

A working operational research and management plan for conserving Minnesota lake resources while confronting major ecological drivers of change; Phase 1 – 2008-2011

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Minnesota Dept. of Natural Resources - Division of Fish and Wildlife

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Executive Summary

SLICE is a cooperative long-term, statewide lake monitoring program led by DNR Fisheries with the support of many other partners. The focus of this interdisciplinary effort is to improve understanding of how major drivers of change such as development, agriculture, climate change, and invasive species can affect lake habitats and fish populations, and to develop a long-term strategy to collect the necessary information to detect undesirable changes in Minnesota lakes.

In Phase I (2008-2011), SLICE will first focus on a diverse set of 24 sentinel lake watersheds spread across four of the state's major ecoregions. In these 24 lake 'laboratories,' DNR and its partners are exploring watershed-scale processes and mechanisms that drive changes in water quality and fish habitat. In Phase II (2012 –), lessons learned from Phase I will be applied to improve the sentinel lakes monitoring schedule and incorporate less intensive surveys of a wider range of lake types. An outcome of Phase II will be a revised lake monitoring program that increases focus on monitoring status indicators that are more sensitive to land use and climate change; reduces focus on past lake survey program elements that have not been cost-effective; and finally, maintains continuity with program elements that have served constituents and managers well.

Cooperation between citizens and multiple entities engaged in aquatic resource management is the foundation of SLICE, and our goal of sustaining viable lake systems is highly relevant to multiple partners. Citizen volunteers, along with multiple units within DNR, PCA, Superior National Forest, US Geological Survey, St. Croix Watershed Research Station, and University of Minnesota and multiple local units of government are successfully executing many coordinated surveys and analyses exploring baseline patterns in watershed conditions, water quality, zooplankton, aquatic plants, and fish communities in the sentinel lakes. In addition to new useful scientific information, a key outcome of SLICE is working towards a model of cooperation among entities to more efficiently accomplish mutually shared goals of aquatic resource sustainability.

Summary of Problem:
Changes to the landscape and climate are placing new constraints on Minnesota lake habitats and biological communities. Large 'footprint' urban development and agricultural practices are growing in extent and contribute large amounts of nutrients and sediments into lakes; increasing demand for lakeshore property has pushed development onto ecologically sensitive marshy shorelines; a highly mobile human population has accelerated the dispersal rate of non-native invasive species. To make matters worse, climate change has the potential to exacerbate these stressors on lake habitats and fish populations, if not fundamentally alter habitat suitability for some species. For example, various studies and models point to increased evaporation, variable precipitation with extended wet and dry periods, longer growing seasons, and warming water temperatures. The net outcome of these stressors is warmer, more productive waters with weakened resilience. Accordingly, the mission of the SLICE program is to monitor major stressors, evaluate their risk to lake habitats and fish communities, inform proactive measures to mitigate the harmful effects of stressors, and finally, continually evaluate whether management actions are successfully delivering fishable and swimmable waters to the citizens of Minnesota.

Long-term strategy and goals:
Current challenges to lake habitats go well beyond the jurisdictional boundaries of DNR Fisheries. Confronting threats to habitats and fish communities will depend on greater cooperation and collaboration among a variety of entities. These include different divisions within the DNR, and Federal agencies (US Geological Survey, USDA Forest Service), State agencies (Minnesota Pollution Control Agency (PCA), Board of Water and Soil Resources), Academia, local units of government (e.g., Soil and Water Conservation Districts and Watershed Districts), Non-governmental Organizations (Midwest Glacial Lakes Partnership, MN Chapter of the American Fisheries Society, MN Waters), and citizen groups (e.g., Lake Associations, angling groups). Through these partnerships we can more effectively clarify the status and trajectory of our lakes, and have the ability to take watershed-scale measures to protect water quality and fish populations.

The DNR Section of Fisheries, with 28 field offices statewide, currently administers a lake survey program that periodically (every 5 – 10 years) surveys game fish populations in a large number of MN lakes (approximately 2200 lakes). Consequently, DNR Fisheries has the necessary infrastructure to support many aspects of SLICE. However, the challenges facing MN fish populations have increased significantly since the last revision to DNR Fisheries lake survey program in 1993. Furthermore, infrequently collecting small amounts of data in many systems has made understanding the cause-effect mechanisms shaping habitats and fish populations in lakes difficult. This has hampered our ability to predict the outcomes of alterations to the landscape on lake habitats and fish populations. With SLICE, we will mesh intensive monitoring in a range of sentinel lakes, with our current extensive approach to lake surveys. This design will allow for greater inference into cause-effect mechanisms with high temporal resolution, while simultaneously monitoring patterns in habitats and fish communities across wide geographic areas. The long-term goals for SLICE are as follows:

1) Monitor relevant climate, land cover, and other environmental stressors.
2) Monitor the effects of stressors on lake habitats and fish communities.

3) Forecast changes to lake habitats and fish populations given possible changes in stressor levels.
4) Outline and evaluate actions taken to mitigate stressors (e.g., land protection/restoration, outreach and education, assistance to local units of government to implement low-impact growth practices), protect or build-up resilience mechanisms in lakes (e.g., harvest restrictions, aquatic plant management policies, shoreland rules), or adapt to unavoidable changes to habitat (e.g., shifting management focus away from failing coldwater fisheries to either coolwater or warmwater fisheries, or identifying resilient refuge habitats for greater protection).

Working towards these goals will require significant pilot work to define stressors, publically available stressor databases (e.g., National Agricultural Statistics Service http://www.nass.usda.gov/), the most appropriate fish and habitat variables to monitor (those that are most sensitive to environmental change), the appropriate frequency to monitor stressors and indicators, and finally to build cooperative partnerships with the numerous other groups engaged in water resource management in Minnesota. Accordingly, a collaborative 4-year pilot project in a set of 24 sentinel lakes (phase 1 of SLICE) is being carried out to aid in the design and implementation of a robust long-term lake-monitoring program (phase 2 of SLICE).

Outline of the sentinel lakes pilot project:

I. Goals:

1. Evaluate historic and recent changes to habitat and fish communities in a set of sentinel lakes representative of the diversity of Minnesota lakes.
2. At the most appropriate biological scale, identify key proxies (if not direct measures) that indicate changes in nutrient and sediment loading, water temperature regimes, hydrologic flows, removal of upland and submersed vegetative or woody cover, human usage patterns, and non-native species invasions.
3. Using lake and watershed models simulate the outcomes of urban development, agricultural practices and climate change on habitats in the sentinel lakes.
4. Identify a set of habitat and fish indicators that are most responsive to climate and land use stressors. Specific stressor (a-d) and indicator (e-h) questions include:
    a. What are the key variables/metrics to measure that best reflect the magnitude of major stressors? At what scale should these stressors be measured?
    b. What stressors are the greatest contributors to increases in nutrients and sediment inputs into the various sentinel lakes?
    c. What are key resilience mechanisms in lakes that must be enhanced or protected?
    d. What potential watershed management actions could offset negative effects due to climate change?
    e. To what degree do water quality, zooplankton, aquatic plant, and fish parameters vary among years across the range of sentinel lakes? What level of sampling effort is required to detect an important change in indicator values?
    f. Which biological indicators are most responsive to environmental change while exhibiting minimal background variability?

    g. What level of sampling and frequency of various parameters is required to track changes in lake status?
    h. What is the relationship between indicators and stressors in different types of lakes; how will stressors borne from land use and climate change affect these relationships.
5. Compare the observed relationship between stressors and indicators of habitat and fish status in sentinel lakes to that in other MN lakes to determine whether the dynamics observed in sentinel lake watersheds are truly representative of the dynamics in other MN lakes.
6. Develop a robust, long-term sampling design to collect stressor and indicator data for statewide inference on current status of lakes, temporal trends in lake status, and for use in forecasting changes to MN lakes under different environmental and management scenarios.

II. Strategy

1. *Overall design*– Phase 1 (2008 – 2012): pilot program to work out sampling protocols, develop simulation models, evaluate most biologically appropriate indicators, and build collaborative relationships in a set of 24 sentinel lakes that are representative of the range of Minnesota's major ecoregions and lake types.
2. *Funding* – Until funding specifically dedicated to the SLICE program can be secured, funding sources that are appropriate for specific SLICE goals will be utilized. This includes the Environmental Trust Fund for aspects of goals 1, 3, and 5, Clean Water Legacy Amendment dollars for aspects of goals 4 and 5, and reimbursements from the Federal Sportfish Restoration Act for aspects of goals 2, 5 and 6.
3. *Partner responsibilities (funding)*
    a. Program Coordinator – Ray Valley (DNR Fisheries Research; Game and Fish Fund, Sportfish Restoration Act). The program coordinator is the primary ambassador for the program. He is primarily responsible for coordinating partner contributions and ensuring that project outcomes are delivered on time. An organizational structure outlining teams, responsibilities, and communication flow ensures that there is order to this complex process. In the appendix, an organizational diagram and team responsibilities are outlined. This diagram is modeled after an adaptive management conceptual model.
    b. DNR Division of Fish and Wildlife (Game and Fish fund; Sportfish Restoration Act) – Primary supporters of the SLICE program. Research and area management staffs are collecting aquatic plant and fish population data in all sentinel lakes. The Fisheries Research Unit will be responsible for most data analysis and dissemination. A detailed copy of this research proposal can be found at http://www.dnr.state.mn.us/fisheries/slice/
    c. DNR Division of Waters and Ecological Resources (Clean Water Legacy, Environmental Trust Fund) – Partners who are delineating lake watersheds, coordinating lake level data, and collecting nearshore fish community, and zooplankton data, and providing important advice on program direction.
    d. PCA Environmental Analysis and Outcomes Division (Clean Water Legacy and Environmental Trust Fund) –Managing all water quality data collection

and coordinating lake-specific reporting as part of their lake assessment program http://www.pca.state.mn.us/water/lakequality.html

  e. US Geological Survey (Environmental Trust Fund, and USGS Cooperative funds) – Detailed mechanistic watershed and lake habitat modeling in three 'super-sentinel' lakes where research and monitoring will be more intensive than the other sentinel lakes.
  f. Science Museum of Minnesota (Environmental Trust Fund) – Paleolimnological reconstructions of historical water quality and correlations to historic landscape and climate changes.
  g. University of Minnesota – Duluth, Department of Biology (Environmental Trust Fund). Hydroacoustic assessments of cold-water cisco populations and explorations into habitat use and feeding behaviors.
  h. Other contributing partners are performing roles ranging from advising project design and conducting parallel scientific investigations (e.g., University of Minnesota-Twin Cities and Natural Resource Research Institute) to assisting with data collection (e.g., DNR Divisions of Parks and Trails; USDA Forest Service-Superior National Forest; several local soil and water management agencies, municipalities, lake associations, and other non government organization with pre-existing water quality programs in the sentinel lakes; and volunteers and citizen groups).

4. *Sentinel lakes selection*
  a. Candidate sentinel lakes were chosen after numerous discussions with PCA and DNR Fisheries researchers and managers.
  b. The number of lakes was capped at 24 because of labor resource constraints.
  c. A gradient approach towards lake selection was chosen that favored a large range of typical Minnesota lake 'types', acknowledging tradeoffs with selecting fewer types of lakes but higher replication. Greater diversity in lake types was favored over replication of any one type of lake.
  d. Lake classification and selection:
    i. Lakes are stratified across 4 major land types and are a hybrid of classifications used by EPA (http://www.epa.gov/wed/pages/ecoregions/level_iii.htm) and DNR's Ecological Classification System (http://www.dnr.state.mn.us/ecs/index.html). These land types are: Shield (glacial-scoured bedrock and mixed coniferous forest); Forest (forested landscapes of glacial drift); Transition (north central hardwood forests transitioning from prairie); and Prairie (prairie and agricultural landscapes contributing to the US "cornbelt") Figure 1; Table 1; N = 4 ecoregions.
    ii. Within ecoregions, our selection was further stratified based on whether the lakes mixed regularly or were stratified (N = 2 mixing classes)
    iii. At the last level in the hierarchy, relative phosphorus enrichment of lakes was evaluated within each ecoregion and within each mixing class (low, average, and high according to water quality data in the EPA's STORET and DNR's lake survey database; N = 3 P-classes).

    iv. The final list of lakes consisted of those that fit the selection criteria and had rich pre-existing water quality and fisheries data sets, or had valuable partnership opportunities. Finally, efforts were taken to distribute lakes evenly among fisheries management areas.

5. *Data Collection and Management*
    a. Table 2 lists all planned surveys in the sentinel and super-sentinel lakes.
    b. Super sentinel lakes will be the sites of highly intensive monitoring with sophisticated digital equipment and models. The super sentinel lakes will be sites where models will be used to:
        i. Predict watershed nutrient loading and in-lake recycling and oxygenated cold water habitat given different land use and climate change scenarios
        ii. Determine the effect of current land conservation practices such as Reinvest in Minnesota (RIM) and Conservation Reserve Program (CRP) parcels on nutrient loading into Carlos Lake. At what scale, and in what areas in Carlos' watershed must new BMP's or acquisition be established to minimize nutrient loading?
    c. Database coordination and management is typically an underfunded critical infrastructure function. For efficient tracking and dissemination of status and trends in aquatic resources, significant investment is needed to ensure data collection and storage meet quality assurance/quality control standards and are housed in a widely accessible database network. Given the range of partners at various levels of organization collecting and housing similar datasets in inaccessible databases, coordination and investment will have to occur at a high-level of State government.
6. *Areas of growth and needed investment*
    a. Several additional areas of growth are detailed in Table 2 that funding and personnel are insufficient to address currently. These components include assessment and monitoring of water balance in our sentinel lakes, examining indicators related to shoreline land use and sensitivity, coarse woody habitat, periphyton, macroinvertebrates, fish health indicators, and contaminants. Investment in these components will help complete the picture of status of our sentinel lakes and may offer more rapid assessment tools to indicate changes in status.
    b. Hydroacoustic technology has advanced considerably over the past decades and represents a cost-effective, high-resolution tool for assessing and mapping aquatic plant abundance, bathymetry, coarse woody habitat, sediment thickness, pelagic fish abundance, and zooplankton. Furthermore, in each of these categories, standard methodology has been developed and hydroacoustics is no longer considered an experimental assessment tool. Finally, informative maps and public information products can be created easily from these data. With an investment in start-up equipment and two full-time employees, great strides in lake ecosystem assessment and monitoring could be made.
    c. Social indicators are another underfunded and critically important aspect to sustaining lakes in a changing environment. What social norms govern good

or bad human behaviors as they relate to lakes? How much do they change through time? What are the most effective methods for persuading people to implement lake-friendly behaviors? Addressing the root cause of lake impairments will be difficult without a focus on socio-economic dimensions.

IV. Outcomes and expected benefits

As a result of this planning effort and pilot project, a statewide lake monitoring system will be designed that is capable of providing timely information to the public on the current status and future outlook for fish populations and supporting habitats in Minnesota lakes. This lake monitoring plan will ensure that appropriate and accurate information to address threats to habitat is available to political decision makers and resource managers before impairments that are difficult to reverse occur. In lakes where fish communities or habitats area already impaired, this monitoring system will provide useful information to managers and policy makers regarding whether restoration activities are leading to gains in habitat and fish populations. Data from a well designed lake monitoring program also improves the ability of the MNDNR to work with various partners needed for protecting and enhancing Minnesota lakes. Some other benefits include:

1. Cause-effect understanding of how stressors on the landscape affect habitat and fish communities, in addition to any time-lags associated with these effects.
2. Intensive sentinel lake monitoring will give us strong inference on *temporal* changes in lake status. Sentinel lake data will be augmented with less-intensive monitoring of many lakes over wider geographic areas gives us strong *spatial* inference on current lake status across Minnesota.
3. Through statistical forecasting models, indicator and stressor data will be used to model risks of impairments to habitat and fish communities. Or, assessing the probability of gains to habitat with various remedial management actions or "best management practices". Ongoing monitoring can validate and improve these statistical models.
4. The collaborative sampling approach will lead to efficiency and data sharing among partners.
5. Outside researchers will benefit from access to comprehensive high quality 'free' data. In turn, managers, policy makers, and other partners may benefit greatly from analyses performed by outside researchers on raw datasets. These partnerships may bring in additional matching grants from outside sources such as the National Science Foundation.
6. Six lakes are currently listed under the Clean Water Act on the State of Minnesota's impaired waters list for excessive nutrients. Several additional sentinel lakes may become listed in the future. Long-term monitoring of the outcomes of federally mandated Total Maximum Daily Loads that are or will be developed for impaired waters will measure the effectiveness of water quality restorations.
7. Outcomes and technical tools developed should inform priority areas of conservation and restoration funding through fish habitat partnerships that are part of the National Fish Habitat Initiative (http://fishhabitat.org/); specifically, the Midwest Glacial Lakes Partnership http://www.midwestglaciallakes.org/); and other restoration grant programs such as the DNR's Shoreland Habitat Program.

8. The ultimate goal is for a more effective, better coordinated lake protection program based on strong, inter-disciplinary scientific analyses.

Table 1. Sentinel lake characteristics. Values are based on most up to date GIS data layers. Watershed acreage reflects all land and water upstream from the each lake's outflow that has the potential to contribute surface flow. P-level is the relative total phosphorus concentration for each lake compared with other lakes in the same ecoregion and depth stratification class.

Ecoregion	Lake	DOW	Acres[b]	Max depth (ft)	Mean Depth (ft)	Watershed Acres	P-level	Stratification	Fish mgt area
Shield	Bearhead	69025400	663	46	14	2,723	med	stratified	Tower
Shield	Elephant	69081000	725	30	15	4,420	high	stratified	International Falls
Shield	Echo	69061500	1,140	11[c]	7[c]	32,069	high	mixed	International Falls
Shield	Tait	16038400	357	15	8	2,708	low	mixed	Grand Marais
Shield	Trout	16004900	260	77	33	1,148	low	stratified	Grand Marais
Shield	White Iron	69000400	3,243	43	19	595,864	med	mixed	Tower
Transition	Belle	47004900[d]	927[d]	22	14	5,207	med	mixed	Hutchinson
Transition	Carlos	21005700	2,607	163	46	156,569	med	stratified	Glenwood
Transition	Cedar	49014000	236	88[c]	36[c]	1,603	low	stratified	Little Falls
Transition	Pearl[a]	73003700	754	18[c]	10[c]	16,311	low	mixed	Montrose
Transition	Peltier[a]	02000400	550	16[c]	7[c]	69,034	high	mixed	East Metro
Transition	South Center[a]	13002700	831	100	14	10,789	high	stratified	Hinckley
Forest	Elk	15001000	300	97[c]	34[c]	8,759	med	stratified	Bemidji
Forest	Hill	01014200	794	48[c]	21[c]	25,736	high	stratified	Aitkin
Forest	Portage[a]	29025000	429	15[c]	8[c]	2,996	high	mixed	Park Rapids
Forest	Red Sand	18038600	511	15[c]	4[c]	4,555	med	mixed	Brainerd
Forest	South Twin	44001400	1,129	29	12	6,745	low	mixed	Detroit Lakes
Forest	Ten Mile	11041300	5,072	208	51	25,510	low	stratified	Walker
Prairie	Artichoke	06000200	1,964	13	8	21,193	high	mixed	Ortonville
Prairie	Carrie	34003200	90	26	10	4,044	low	stratified	Spicer
Prairie	Madison[a]	07004400	1,443	58	10	11,167	high	stratified	Waterville
Prairie	Shaokotan[a]	41008900	996	11	8	8,817	med	mixed	Windom
Prairie	St James	83004300	203	14[c]	5[c]	2,340	low	mixed	Windom
Prairie	St Olaf	81000300	91	30	14	278	med	stratified	Waterville

[a]Listed on the 303d Impaired Waters List for excessive nutrients.
[b]Figures derived from DNR 100K Lakes and Rivers GIS layer (http://deli.dnr.state.mn.us/data_search.html) and updated annually based on water levels
[c]Data based on updated (post 2008) bathymetry data.
[d]Despite DNR Division of Waters, legal descriptions that separate the small attached unnamed north basin from the main basin into different sub-basins, for purposes here we consider DOW # 47004900 to be one 930 acre basin.

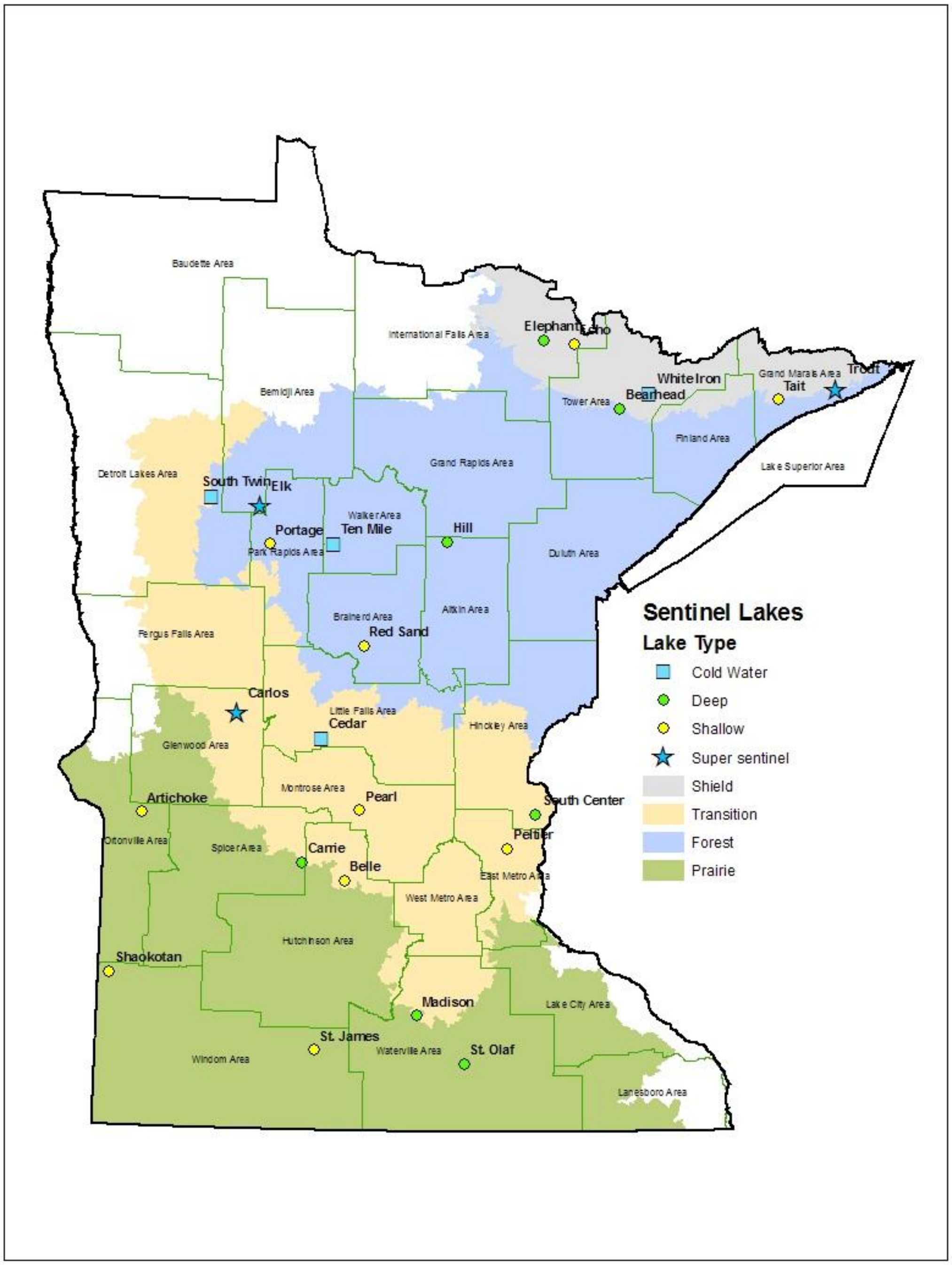


Figure 1. Map of sentinel lakes, major land types, and DNR Area Fisheries Office jurisdictions. "Deep" lakes stratify during the summer. "Shallow" lakes are defined here as those that mix continuously throughout the summer. "Cold Water" lakes are those that either harbor cisco populations, lake whitefish, or lake trout and are the focus of research funded by the Environmental Trust Fund (ETF). "Super sentinel" lakes also harbor cold-water fish populations and research on these lakes is also funded by the ETF.

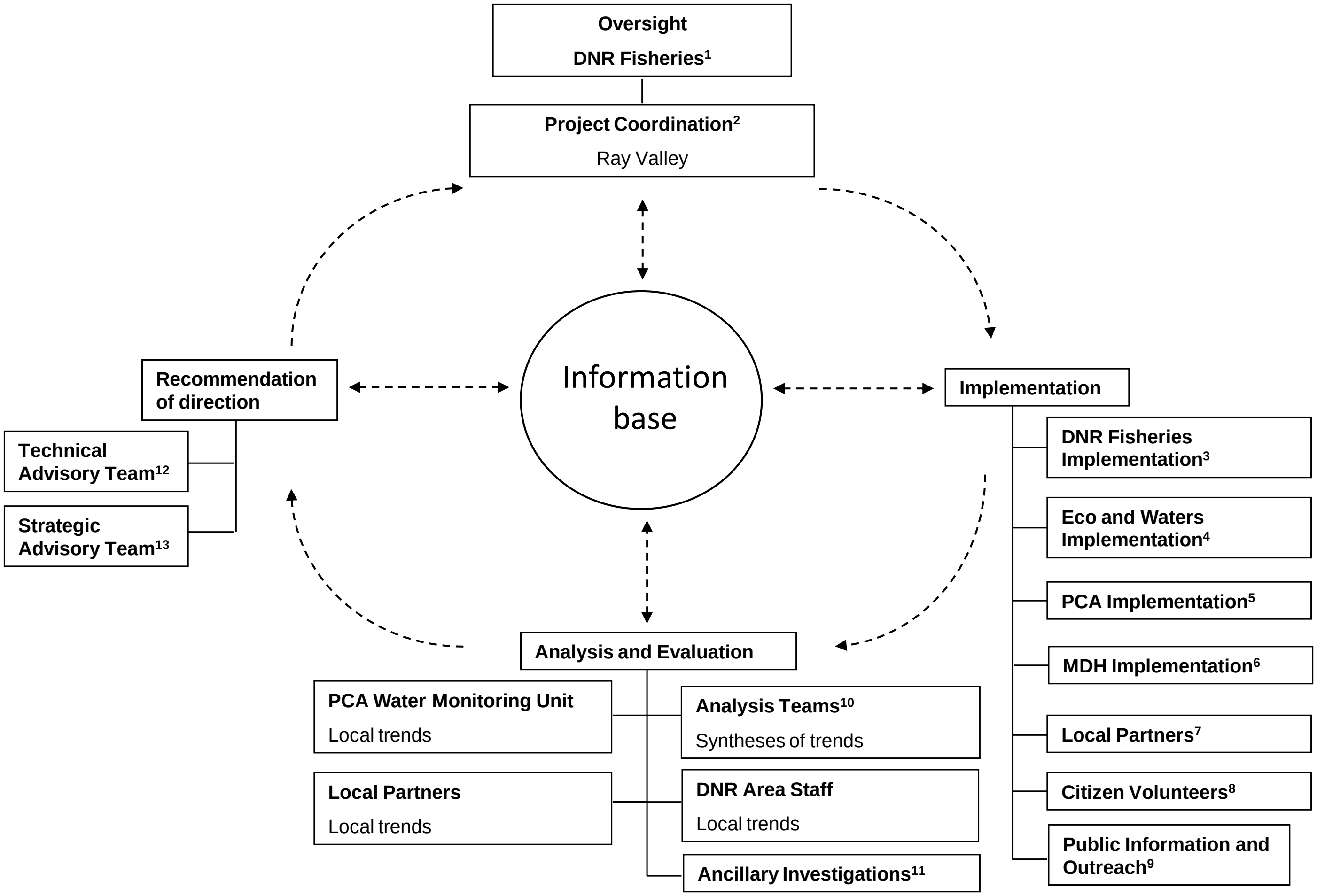
Table 2. List of all proposed sampling activities and main supporters. For the budget column, GF = Game and Fish Fund, ETF = Environmental Trust Fund, CWL = Clean Water Legacy, V = volunteer "free" data; O = partner operating budgets, NF = not funded.

Surveys	Indicator	Sentinel	Super Sentinel	Sampling Method	Frequency	Primary Budget	Volunteer involvement	Leader/admin.
Evaporation	Climate		x	Data platform	Continuous	ETF		USGS
Ice-off	Climate	x	x	Direct observation	Daily	V	x	State Climate Office
Lake levels	Climate	x	x	Lake gauging stations	Weekly	V	x	DNR Eco&Waters
Precipitation	Climate	x	x	Direct observation	Continuous	ETF	x	USGS
Rel. humidity	Climate		x	Data platform	Continuous	ETF		USGS
Solar radiation	Climate		x	Data platform	Continuous	ETF		USGS
Tributary flow	Climate		x	Trib. gauging stations	Continuous	ETF		USGS
Wind energy	Climate		x	Data platform	Continuous	ETF		USGS
Fish IBI	Fish	x	x	Standard Methodology	Annually	CWL		DNR Eco&Waters
Pike surveys	Fish	x	x	Standard Methodology	Annually	GF		DNR Fisheries
Bass surveys	Fish	x	x	Standard Methodology	Annually	GF		DNR Fisheries
Community comp.	Fish	x	x	Standard Methodology	Annually	GF		DNR Fisheries
Fish health	Fish			TBD	TBD	NF		TBD
Temp. profiles	Habitat		x	Data platform	Continuous	ETF		USGS
Temp/O_2 profiles	Habitat	x	x	Standard Methodology	Bi-monthly	V	x	PCA
Epilimnetic Temp.	Habitat	x		Temperature loggers	Continuous	GF		DNR Fisheries
Water clarity	Habitat	x	x	Standard Methodology	Bi-monthly	V	x	PCA
Total Phosphorus	Habitat	x	x	Standard Methodology	Monthly	CWL&ETF		PCA
Total Nitrogen	Habitat	x	x	Standard Methodology	Monthly	CWL&ETF		PCA
Nitrates	Habitat	x	x	Standard Methodology	Monthly	CWL&ETF		PCA
Chlorophyll a	Habitat	x	x	Standard Methodology	Monthly	CWL&ETF		PCA
pH	Habitat	x	x	Standard Methodology	Monthly	CWL&ETF		PCA
Tot. Sus. Solids	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Tot. Sus. Vol.	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
TOC	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
DOC	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Alkalinity	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Calcium	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA

Magnesium	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Sodium	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Potassium	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Sulfate	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Chloride	Habitat	x	x	Standard Methodology	Bi-monthly	CWL&ETF		PCA
Planktonic algae	Habitat			TBD	TBD	NF		TBD
Periphyton	Habitat			TBD	TBD	NF		TBD
Zooplankton	Habitat	x	x	Standard Methodology	Monthly	ETF		DNR Eco&Waters
Macroinvertbrates	Habitat			TBD	TBD	NF		TBD
Aq. plant comm.	Habitat	x	x	Point-intercept	Annually	GF	x	DNR Fisheries
Curly-leaf pondweed	Habitat	x	x	Point-intercept	Bi-annually	GF	x	DNR Fisheries
Submerged plant mapping	Habitat	x	x	Hydroacoustics	Variable	GF		DNR Fisheries
Emergent plant mapping	Habitat			GPS mapping	Every 5 yrs	NF		TBD
Coarse woody habitat	Habitat			TBD	Decadal	NF		TBD
Historical productivity	Habitat	x	x	Fossil diatoms	initial	ETF		MN Sci. Museum
Agricultural practices	Land Cover	x	x	NASS[a]	Annual	GF		USDA
Riparian landcover	Land Cover			TBD	Every 5 yrs	NF		TBD
Wshd Land cover	Land Cover	x		NLCD[b]	2001	GF		MRLC
Wshd Land cover	Land Cover		x	Aerial photo interp	Every 5 yrs	ETF		USGS
Wshd Land cover proj.	Land Cover	x	x	Change projections	decadal	ETF		USGS
P loading	Land Cover		x	Intensive P loading est.	annual	ETF		USGS
P loading	Land Cover	x		P loading estimation	Every 5yrs	O		PCA
Sedimentation	Land Cover			Hydroacoustics	decadal	NF		TBD
Sedimentation	Land Cover		x	Sediment cores	initial	ETF		MN Sci. Museum
Timber harvest	Land Cover	x	x	Forestry records	annual	GF		DNR Forestry/USFS
Bathymetry	Morphometric	x	x	Hydroacoustics	Initial	GF		DNR Fisheries
Watershed delineations	Morphometric	x	x	Standard methodology	Initial	O		DNR Waters
Groundwater dynamics	Morphometric		x	Stable isotopes		CWL		U of MN
Contaminants	Human health			TBD		NF		TBD
Human dimensions	Social			TBD		NF		TBD

[a]USDA National Agricultural Statistical Service (http://www.nass.usda.gov/)
[b]National Land Cover Database (http://www.mrlc.gov/index.php)

Appendix



*See footnote descriptions in following pages

Figure A1. Chart displaying program processes, information flow, involved partners, and allocation of responsibilities. Boxes and sub-boxes represent specific program components. Dashed double-arrow lines represent coordination and information flow pathways.

Appendix

Organizational structure and decision-making process (refer to Figure A1.)
This is a 'working' organizational structure that is subject to change according to shifting Department and Division priorities, budgets, and personnel. Some players and teams identified may become more or less involved over time. Over the short- and long-term, new partners may come on the scene and some may recede. This plan will be continually updated to reflect these changes. Nevertheless, the mission and over-arching objectives of SLICE will remain consistent through time.

[1]DNR Fisheries Oversight:

Who: Division of Fish and Wildlife Director, Section of Fisheries Chief, or relevant program leaders

Duties:

- Administers Division programs cooperating on surveys and facilitates SLICE program implementation.
- High level SLICE program ambassadors delivering key messages to key decision makers and staff to ensure continued program viability and relevance.
- Provides guidance and advice to the Program Coordinator regarding SLICE strategic direction and process (e.g., implementation, evaluation, communication)

[2]Project coordinator:

Who: 14L MAPE Natural Resource Program Coordinator (Currently Ray Valley). Position is housed in DNR Fisheries Research

Duties:

- Overall project coordination and management of the organizational structure (e.g., managing communications, assigning job responsibilities, scheduling meetings, following up on action items)
- Chairs the Advisory Team
- Coordinates with other DNR field staff, partners, and stakeholders
- Maintains a calendar of field activities and responsibilities
- Ensures objectives and timelines will be met with available resources.
- Pursues other partnerships or funding to meet long-term program goals.
- Prepares progress and final reports and manuscripts
- Coordinates and manages the delivery of public information products (e.g., website, lake fact sheets)
- Data management and coordination with other data managing entities to ensure information exchange between databases.
- Coordinates with other federal or state supported lake survey programs to maximize mutual benefits and efficiency.
- Attends meetings and delivers technical presentations on major findings.

[3]DNR Fisheries Implementation

Who: Assistant Regional Fisheries Managers; Area Fisheries Supervisors and Area Representatives, Fisheries Research Staff

Appendix

<u>Area Representatives:</u>
Aitkin – Rick Bruesewitz (Area Supervisor)
Bemidji – Mike Habrat (Area Specialist)
Brainerd – David Bohlander (Assistant Area Supervisor)
Detroit Lakes – Mandy Erickson (Area Specialist)
East Metro – David Gilbraith (Area Technician)
Glenwood – Jed Anderson (Area Specialist)
Grand Marais – Steve Persons (Area Supervisor)
Hinckley – Deb Sewell (Area Specialist)
Hutchinson – Chris Foster (Area Specialist)
International Falls – Tom Burri (Area Specialist)
Little Falls – Carl Bublitz (Area Specialist)
Montrose – Joe Stewig (Assistant Area Supervisor)
Ortonville – Chris Domeier (Assistant Area Supervisor)
Park Rapids – Doug Kingsley (Area Supervisor)
Spicer – Brad Carlson (Area Specialist)
Tower – Jeff Eibler (Assistant Area Supervisor)
Walker – Calub Shavlik (Area Specialist)
Waterville – Marc Bacigalupi (Assistant Area Supervisor)
Windom – Brian Schultz (Assistant Area Supervisor)

Duties (Managers and Supervisors):

- Manages workloads to accommodate needs of the SLICE program
- Communicates workload challenges to Regional Fisheries Manager who confers with the Program Coordinator on possible solutions

Duties (Area Representatives):

- Managing field crews and fisheries and aquatic plant data collection
- Assists data collection
- Ensures data is entered into the appropriate databases
- Local expertise on history and current management of the lake and watershed
- Liaison with local partners
- Local investigations into lake-specific status and trends.
- Completion of annual fish population assessment reports
-

[4]Ecological and Waters Implementation

Who: Fish IBI Program (Kim Strand); zooplankton data collection (Jodie Hirsch)

Duties:

- Either conducts surveys or coordinates with other partners collecting samples or data
- Manages data and provides progress reports and data to the Program Coordinator

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[5]PCA Implementation

Who: Environmental Analysis and Outcomes Division; Water Monitoring Section; Lakes and Streams Monitoring Unit Supervisor and Staff

Supervisor:
Dana Vanderbosch

Technical Lead:
Steve Heiskary – Research Scientist

Lake Monitoring Staff:
Jesse Anderson – Trout, White Iron, Bearhead, Tait, Echo, Elephant
Kelly O'Hara – Portage, Hill, Ten Mile, Elk, South Twin
Pam Anderson – Pearl, Red Sand, Cedar, Belle
Lee Engel – Shaokotan, Carlos, Artichoke, Carrie, South Center
Matt Lindon – Peltier, Madison, St. Olaf, St. James

Duties (Dana Vanderbosch; Supervisor):

- Primary PCA liaison to DNR
- Coordinates lake monitoring staff to accommodate agreed-upon needs of the SLICE program
- Communicates workload challenges to the Program Coordinator and discusses possible solutions
- Co-editor on cooperative lake assessment reports

Duties (Steve Heiskary):

- Technical lead on water quality collection, analytical budget, and data management
- Technical review of all lake assessment reports

Duties (Lake Monitoring Staff):

- Water quality data collection and coordination
- Water quality data management
- Volunteer coordination
- Lead author on lake assessment reports

[6]Minnesota Department of Health (MDH) Implementation

Who: Public Health Laboratory Division

Duties:

- Analyzes water quality samples submitted by PCA
- Reports findings to PCA

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[7]Local Partners

Who: Other local DNR units, external agencies, and local government units assisting with data collection and analysis. Major partners include DNR Parks (Carlos, Bearhead, and Elk Lakes), Superior National Forest (Elephant, Echo, Bearhead, White Iron, Tait, and Trout), Rice Creek Watershed District (Peltier), U of MN Itasca Biological Station (Elk), DNR Shallow Lakes Program (Artichoke), Yellow Medicine Watershed District (Shaokotan), Sauk River Watershed District (Pearl), White Iron Coalition of Lake Associations.

[8]Citizen Volunteers

Who: Citizen Lake Monitoring Program, Lake Level readers, Master Naturalist Program

[9]Public Information and Outreach

- Press releases, website design, other communication tools
- DNR Fish and Wildlife Information Officer (Pete Takash)

[10]Analysis Teams

Who: Personnel and partners with specific technical tasks related to data collection, management, analysis, and dissemination.

<u>Ice data:</u>
Greg Spoden (DNR/U of MN Climate Working Group)

<u>Water Levels:</u>
Sandy Fecht – Lake level coordinator (DNR Ecological and Water Resources)

<u>Water Quality:</u>
Steve Heiskary – Research Scientist (PCA Water Monitoring Section)
Dr. Mark Edlund – Research Scientist; St. Croix Watershed Research Station)

<u>Zooplankton:</u>
Jodie Hirsch – Invertebrate Biologist (DNR Ecological and Water Resources)
Jeff Reed – Research Biologist (DNR Fisheries)

<u>Aquatic Plants:</u>
Cindy Tomcko – Research Biologist (DNR Fisheries)
Donna Dustin – Research Biologist (DNR Fisheries)
Ray Valley – Research Biologist and SLICE Program Coordinator (DNR Fisheries)

<u>Fish:</u>
Mike McInerny (Population indicators) – Research Biologist (DNR Fisheries)
John Hoxmeier (Population indicators) – Research Scientist (DNR Fisheries)

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GIS Analyses and Support:
Lyn Berquist – GIS program coordinator (DNR Fisheries)
Andrew Williquet – GIS Data Analyst (DNR Fisheries)

Watershed and Lake Modeling:
Dr. Richard Kiesling – Limnologist (US Geological Survey; Water Science Center)
Steve Heiskary – Research Scientist (PCA Water Monitoring Section)
Jim Solstad (ad-hoc) – Senior Hydrologist (DNR Ecological and Water Resources)

Indicator and Status Assessment:
Dr. David Staples – Biometrician (DNR Fisheries)
Ray Valley – Research Biologist and SLICE Project Coordinator (DNR Fisheries)

Stressor Assessment:
Peter Jacobson – Habitat Research Supervisor (DNR Fisheries)
Ray Valley – Research Biologist and SLICE Project Coordinator (DNR Fisheries)
TBD Ad Hoc contributors

Duties:

- Subject experts on components of SLICE
- Develops testable hypotheses on specific subject matter
- Drafts appropriate sampling and analysis protocols to address hypotheses
- Collects and in some cases manages lake data
- Analyzes appropriate data and submits reports to the Project Coordinator.
- Available for consultation and technical support

[11]Ancillary Investigations

- Independent investigations from outside collaborators
- Investigations include study of sentinel lakes
- Investigations of specific research questions
- Active research projects include:

1. Forecast modeling of future habitat conditions for cisco given climate change scenarios (Dr. Heinz Stefan – University of Minnesota; Dr. Xing Fang – Auburn University; Peter Jacobson – MN DNR Fisheries Research; Dr. Richard Kiesling – US Geological Survey; Lakes: Carlos, Cedar, Elk, South Twin, Ten Mile, Trout, White Iron)

2. Managing the Nations Fish Habitat at Multiple Spatial Scales in a Rapidly Changing Climate (Drs. Craig Paukert, Steven Hostetler, Jeffrey Kershner , Tyler Wagner, Joanna Whittier – US Geological Survey; C. Paola Ferreri – Pennsylvania State University; Drs. Dana Infante, Lizhu Wang – Michigan State University; Peter Jacobson – MN DNR Fisheries Research; Dr. Lucinda Johnson – Natural Resource Research Institute; Dr. Julian Olden – University of Washington; Dr. Donald Pereira - MN DNR Fisheries Research; Gary Whelan – MI DNR Fisheries

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[12]**Technical Advisory Team:**

Who: Representatives from DNR Fisheries Research, Fisheries Management, Ecological and Water Resources, and PCA Lakes and Streams Monitoring Unit:

DNR Fisheries Research Unit:

Tim Cross, Mike McInerny, Donna Dustin, Dr. David Staples, Dr. Charles Anderson, Melissa Drake, Peter Jacobson

DNR Fisheries Management:

Northeast – Tom Jones (Large Lake Specialist Aitkin), Steve Persons (Grand Marais Fisheries Area Supervisor)

Northwest – Doug Kingsley (Park Rapids Area Fisheries Supervisor), Mandy Erickson (Detroit Lakes Area Fisheries Specialist)

Central – Paul Diedrich (Montrose Area Fisheries Supervisor), Deb Sewell (Hinckley Area Fisheries Specialist)

Southwest – Brad Carlson (Spicer Area Fisheries Specialist), Chris Domeier (Ortonville Assistant Area Fisheries Supervisor)

Al Stevens – Lake Survey Program consultant

Mike Duval – Lake Coordinator

DNR Ecological and Water Resources

Dr. David Wright – Monitoring and Control Unit Supervisor

Paul Radomski (rep in 2010) – Research Scientist

PCA Lakes and Streams Monitoring Unit

Steve Heiskary – Research Scientist

Duties

- The SLICE ‘think tank’ and ‘sounding board’ for the project coordinator
- Provides recommendations to the oversight committee on major program design elements (e.g., program scope, goals, objectives, strategies, sentinel lake selection)
- Rules independently on minor program adjustments (e.g., parameter or survey tweaking).
- Identifies mechanisms of implementation

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[13]Strategic Advisory Team:

Who: DNR Division of Ecological and Water Resources program leaders and administrators, PCA Environmental Analysis and Outcomes Division program leaders and administrators

Duties:

- Communicates to the project coordinator changing division priorities that may affect their involvement in the SLICE partnership (either more or less involvement).
- Recommends ways SLICE can remain relevant to their programs and constituents and recommends strategies to achieve mutually shared objectives

Ad Hoc Contributors

- Subject matter experts that have played important roles in the design and implementation of SLICE.
- Are consulted with on an Ad Hoc basis for technical expertise
- Subject to change and contributors may move into more active roles as the program develops.
- Major contributors include:

DNR Fisheries

Dr. Andy Carlson
Brad Parsons
Brian Herwig
Doug Kingsley
Henry Drewes
Jeff Reed
Jerry Younk
Dr. Dan Isermann (now with U of WI – Steven's Point)
Jack Wingate (retired)
Cindy Tomcko
Rod Pierce
Tim Cross
Dr. Douglas Dieterman

DNR Wildlife

Nicole Hansel-Welch
Dr. Mark Hanson

DNR Ecological and Water Resources

Sean Vaughn
Jim Solstad
Norm Aaseng
Daren Carlson
Brian Stenquist

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Ian Chisholm
Donna Perleberg
Mark Briggs
Gary Montz

Academia

Dr. Lucinda Johnson (UMD - Natural Resources Research Institute)
Jennifer Olker (UMD - Natural Resources Research Institute)
Dr. Kyle Zimmer (St. Thomas)

MN PCA

Dr. Ed Swain
Dr. Bruce Monson

Minnesota Department of Health

Patricia McCann