An Assessment of the Communicability of the International Joint Commission Ecosystem Indicators and Metrics

Prepared by the
Great Lakes Science Advisory Board
Science Priority Committee
Communication Indicator Workgroup

Submitted to the International Joint Commission

April 2016

Acknowledgements

The Great Lakes Science Advisory Board's Science Priority Committee would like to acknowledge the excellent and extensive efforts of the Communication Indicator Work Group and other contributors and reviewers of this report, as identified below.

Primary Authors: Jessica McKinnon, Christina Semeniuk and Scott Sowa

Contributors and Reviewers: David Allan, Raj Bejankiwar, Lindsay Chadderton, Matthew Child, Gavin Christie, Sally Cole-Misch, Lauren Fry, Norm Grannemann, Drew Gronewold, Bob Hecky, Matt Herbert, Christine Indrigo, Lucinda Johnson, Mary Khoury, Roger Knight, Debbie Lee, Michael Murray, Carolyn O'Neill, Victor Serveiss, Ed Rutherford, Dale Phenicie, Michael Twiss, David Ullrich, Li Wang and Chris Winslow

Executive Summary

Background

Assessing and reporting on the condition of the Great Lakes is a daunting challenge, and communicating the findings to the public can be equally demanding. In 2014 another International Joint Commission (IJC) workgroup, with members from the Science Advisory Board (SAB) and other boards, identified a suite of 16 ecosystem indicators composed of 41 metrics to assess progress towards achieving the objectives of the 2012 Great Lakes Water Quality Agreement (GLWQA)[1]. Although the IJC agreed that this set of ecosystem indicators provides good coverage of the Agreement Objectives and Annexes with the smallest number of indicators possible, they also felt that 16 indicators and over 40 metrics were simply too many to clearly communicate progress to the public.

Charge from Commissioners to Science Priority Committee

The SAB provides scientific advice to the IJC, and is one of its Great Lakes Advisory Boards. The SAB is made up of the Science Priority Committee (SPC) and the Research Coordination Committee (RCC). In April 2014, the IJC asked the SPC to identify a smaller set of indicators and metrics from this existing set that could be the focus of public communications. The SPC was asked to:

1) develop and implement a process for assessing and prioritizing the existing set of 16 ecosystem indicators into a smaller set of indicators and

2) Select a smaller set of indicators and metrics that can "tell meaningful and compelling stories" to the public about the health of the Great Lakes and to reflect the progress made by the governments towards the objectives of the Agreement.

[1] Can be accessed at http://www.ijc.org/files/publications/Ecosystem%20Indicators%20-Final.pdf.

The SPC accepted the challenge and established a goal statement for the project:

- Provide a comparative assessment of the current communicability of the 16 ecosystem indicators and 41 associated metrics to identify a smaller subset of indicators and metrics that could be the focus of the IJC's 2017 Triennial Assessment of Progress (TAP) report.

To achieve this goal two key steps were completed:

1. Develop a process for assessing the communicability of ecosystem indicators and metrics.
2. Apply the process to assess the current communicability of the 16 ecosystem indicators and associated metrics to identify a smaller subset of indicators and metrics.

The SPC used the results from the communicability assessment to provide recommendations on the indicators and metrics that should be the focus of the 2017 TAP report, and longer term recommendations on the investments and actions needed to improve the communicability of the ecosystem indicators and metrics and the ability to effectively communicate progress towards meeting GLWQA objectives in future TAPs.

Process - objective, repeatable, defensible and transferrable:

To select the indicators and metrics, the SPC could have developed a simple expert opinion process. For instance, experts could have scored each indicator and metric and decisions could have been based on the results of the scoring. While this may have been the quickest process to obtain results, the SPC felt such a simple process was inappropriate for this task. The SPC agreed that it needed a process that would be objective, repeatable, defensible and transferrable to other ecosystem indicators (e.g., human health, socioeconomic) for several reasons:

- Our knowledge and understanding of the Great Lakes ecosystem will change
- Technology will change and allow us to measure things better or measure new things
- Stressors impacting the lakes will change and the ecology of the lakes will change.

Shifts in public attitudes and/or socioeconomic status will precipitate changes in the relative valuations of the benefits that the Great Lakes ecosystem provides to the public.

For these and other reasons the suite of indicators and metrics we will use to effectively communicate progress toward GLWQA objectives will most certainly change. Consequently, the SPC took the time to develop a more objective, repeatable and scientifically defensible assessment process and believes this process, outlined in this report, should be regularly repeated.

Assessment of communicability - a two-tier process:

Each of the 16 ecosystem indicators is composed of multiple metrics. The SPC first selected a smaller set of indicators (from the set of 16) and then picked a set of metrics for the selected indicators. Our process therefore consisted of both an indicator and metric-level assessment of communicability.

Indicator-level process

To select a smaller set of indicators from the set of 16, four filters were used to provide a general and broad assessment of communicability to the public:

1. Compelling story – Relationship to public interest about lakes being fishable, swimmable and drinkable
2. Visible – Ability of public to see or sense changes
3. Easy to understand – Ability to understand how the indicator relates to things they care about
4. Direct measure of lake health – Reflection of lake health as opposed to a disturbance or stressor.

The indicator prioritization process ranked all the ecosystem indicators from 1-16 in terms of their ability to communicate with the public and that provide a balanced coverage of indicators that align with the overall purpose of the GLWQA, "...to restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes." From this process, six indicators were selected to represent the interface between science and the public.

Metric-level process

There were 28 metrics associated with the six indicators identified by the indicator-level assessment (tier one). Then the metric-level prioritization process (tier two) was applied to choose the metric(s) that could best communicate the importance of each indicator to the public. Seven filter categories were used:

1. Comprehensive data across basin – Availability of data across the Great Lakes basin
2. Rigorously monitored – Sampling design and sample size of data collection to be reliable statistically at all the places the data are collected
3. Regularly monitored – Frequency and consistency of data collection

4. Length of monitoring record – Length of time that data have been collected
5. Calibration and endpoints – Ability to account for natural variation, monitoring methods, and have a meaningful endpoint, goal, standard, or range
6. Owner and cost – Reliability of owner, funding availability, and reasonable cost
7. Communicable, interconnected and useful – Ability of data to reflect a trend, tell a story, and be useful for making decisions.

Results

There was much debate among the SPC members on what was the “right” number of indicators to recommend to the IJC to focus on for the 2017 TAP. While there is no right answer the SPC wavered between four and six indicators before settling on 6. These six represent a collection of the top scoring indicators within each of the three categories of ecosystem integrity (chemical, physical, and biological) (See table 2 below). The SPC felt it was important to ensure the selected set of indicators provided balance across these three categories to align with the overarching purpose of the Agreement, as stated above. The fact that there is no right number of indicators is further supported by the request from the IJC that asked the SPC to add two more indicators– aquatic invasive species and chemicals of mutual concern. A work group of the SAB is using the SPC’s metric-level assessment process to identify best metrics for these two indicators and these results have been summarized in a separate SAB report (see Appendix E).

Selecting six indicators from the original set of 16 provided an easier task than selecting a representative metric for each of these six indicators. Any multimetric indicator, like the Gross Domestic Product, by their very nature provides a broad measure of some condition and the six selected ecosystem indicators are no exception. Given this breadth it is difficult to identify any single metric that adequately represents the full breadth of conditions that the indicator was designed to measure. However, through the metric-level process the SPC was able to identify a "top" metric for each indicator in all but one instance. The abundance of lake trout and lake whitefish is a suitable metric for the "Fish Species of Interest" indicator in all of the Great Lakes, except Lake Erie where walleye abundance provide a more meaningful metric. The SPC also found a great deal of variation in the availability and quality of the monitoring data across the metrics, which also played a large role in determining which metric was ultimately selected for each indicator.

All of the metrics have some data availability, resolution and/or quality issues that impact their communicability. Specifically, the average communicability scores were much higher for those metrics associated with the physical and chemical indicators compared with those for the biological indicators. Also, many of the metrics do not have sufficient data to be able assess and report on ecosystem conditions for individual lakes or subunits of these lakes. This makes it difficult to identify and relate trends (i.e., for ease of public interpretation) in these metrics to changes in human disturbance and/or management activities that affect these metrics. These findings are not necessarily surprising but are concerning and must be addressed over the longer term in order to continue to improve our ability to assess, report and communicate on progress to meet the objectives of the GLWQA.

Recommendations

For the 2017 Triennial Assessment of Progress

The bullets below show the SPC's recommended set of six ecosystem indicators and their highest-scoring metrics based on the indicator and metric-level assessments of communicability. The following indicators and metrics were selected:

- Harmful and nuisance algae – nuisance algal blooms
- Fish species of interest – Lake trout/lake whitefish adult abundance (walleye for Lake Erie)
- Phosphorus loads and in-lake concentrations – Total phosphorus in lakes
- Persistent bioaccumulating toxics (PBT) in biota – PBTs in whole fish
- Water temperature – Maximum ice cover
- Water level – Long-term water level variability

The SPC recommends that the IJC focus the 2017 TAP around this set of indicators and metrics, plus the two additional indicators added by the IJC and the metrics that have been reported separately by a work group of the SAB (see Appendix E). However, these recommendations should to some extent be examined more holistically. More specifically, the storylines for the 2017 TAP should be initially and primarily built around these recommended set of indicators and metrics but, if necessary, this set should be amended to help the IJC achieve the primary objective of the TAPs: to tell meaningful, compelling and complete stories to the public.

For the 2020 and future TAPs

The SPC strongly believes that the IJC should continually strive to improve its ability to tell meaningful, compelling and complete stories to decision makers and the public through the

TAPs and other means of communication. The rigorous assessment processes developed and used for this report provided the SPC with an unprecedented view into some of the factors hindering the IJC's ability to tell such stories. Here we provide recommendations for specifically addressing these factors and helping to improve future TAPs.

Focus on telling complete stories: Reporting on the status and trends in the ecological health of the Great Lakes is important, as those conditions are directly associated with the major objectives of the GLWQA. However, status and trends in ecosystem indicators alone do not provide sufficient information to the programs in charge of adaptively managing this treasured resource, or to the public on how well these programs are accomplishing their goals. Ecosystem indicators need to be bundled with human health, program and socioeconomic indicators, and communicated to the public and decision makers in a manner that answers the following question; "How are our investments and management programs doing to address the key stressors and helping to maintain or restore the ecological and socioeconomic conditions associated with the GLWQA Objectives?" Answering all facets of this question provides decision makers and the public with not just compelling stories, but more importantly complete stories that lead to better programs, policies and management decisions, and ultimately a healthier Great Lakes. Therefore, all other things being equal, efforts to tell complete stories should be the focus of communicating with these audiences.

Focus more attention on effective management and delivery of information: As this report clearly demonstrates, there are many factors that affect our ability to communicate useful information to decision makers and the public. Many of those factors are associated with the quality and quantity of the data we collect. However, effective communication goes beyond just collecting the right data. Equally important is how those data are managed and how they are delivered to the target audience(s). The SPC recommends that in the future the IJC and the Parties place as much or more emphasis on the effective management and delivery of information, including identifying the appropriate target audience, as they have to the identification of the indicators and metrics and the collection of the monitoring data.

Improve the communicability of the ecosystem indicators and metrics: This project identified many key data gaps and other factors that affect the communicability of ecosystem indicators and metrics. There is a wealth of knowledge and information captured in the results and summary sections of this report that the IJC and the Parties should use to help prioritize investments and efforts to improve the communicability of the ecosystem indicators and metrics.

Expand the process to all of the ecosystem indicators and metrics: Throughout this assessment process the IJC has stressed that it is ultimately committed to all 16 ecosystem indicators and associated metrics for assessing progress toward meeting the GLWQA objectives, but not necessarily for communicating with the public. The SPC applauds this commitment, but believes that all 16 of the ecosystem indicators and metrics should be run through this communicability assessment process. This would help to identify key data gaps and provide a more comprehensive set of information to prioritize efforts to address these gaps.

Expand the process to the other types of indicators: The SPC also believes the IJC should expand the assessment process to other indicators (e.g., human health and program indicators).

As noted above, telling complete stories around our collective efforts to meet GLWQA objectives requires reporting on bundles of indicators across all of these different types of indicators. Ultimately, our ability to communicate such stories will be significantly influenced or determined by the least communicable indicator. Expanding this process to all of these indicators would allow us to examine our ability to communicate these stories more holistically rather than for individual indicators or metrics. The SPC believes the process detailed in this report is directly transferable to these other types of indicators with minimal or no need to amend the process.

Expand the process to include a broader set of stakeholders:

Given time and funding constraints, most of the people that participated in this assessment were scientists and/or members of the monitoring community. The IJC should expand this process to solicit input from a broader set of stakeholders. In particular, the Indicator-level assessment process would benefit by input from the public (e.g., concerned citizen groups) and policy makers. The metric-level process would benefit from input from program administrators, particularly those who can help with determining or calculating monitoring costs.

Improve the process by incorporating costs:

The SPC believes that monitoring costs are a critical factor for prioritizing and selecting metrics for long-term monitoring. Monitoring can be very expensive and if two metrics provide relatively similar information, the one with the lower monitoring cost should be chosen. Unfortunately, despite our best efforts the SPC was unable to calculate monitoring costs for a single metric. We recommend the IJC put in place processes that allow for the accurate calculation of monitoring costs for each metric and indicator so they can assess costs and benefits in our decisions on where to invest to improve our monitoring programs and the overall quality of the triennial reports.

Improve the metric level process by slightly regrouping the filters:

Hindsight is always 20/20 and upon completing the metric-level assessment the SPC realized that a slight regrouping of the filters would improve the overall assessment and interpretation of the results. Specifically the metric-level filters should be grouped according to the four distinct factors that affect communicability: data availability, science and policy, program operations, and general ability to communicate.

Regularly repeat the process:

The SPC strongly recommends that the IJC establish a regular cycle for repeating the communicability assessment covered in this report. This will provide a regular assessment of the ability of the selected indicators and metrics to communicate with decision makers and the public. The SPC believes that a six to nine-year assessment cycle that aligns with the triennial reports would be a reasonable cycle for repeating this assessment process. Regularly repeating this process will show if we are actually acting upon the recommendations in this report and making progress in monitoring, assessment, and reporting efforts and improving communicability of the ecosystem indicators and metrics. Furthermore, as noted above, the suite of indicators and metrics we will need to use to effectively communicate progress toward GLWQA objectives will most certainly change in the future and repeating this process will help the IJC better identify if and when those changes are needed.

Table of Contents

List of Tables

LIST OF APPENDICES

1 Introduction

The background, purpose and scope of this report are provided in the following sections.

1.1 Background

The International Joint Commission (IJC) was formed through the Boundary Waters Treaty of 1909 and it is the role of the IJC to prevent and resolve disputes relating to the use and quality of the transboundary waters shared by the two nations.[2] Under the Great Lakes Water Quality Agreement (GLWQA) of 1972, the IJC's role is to assess the progress made by the Parties towards achieving the objectives of GLWQA, facilitate binational cooperation and public engagement and outreach, and provide scientific advice to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes.[3]

Assessing and reporting on the ecological integrity of something as large and complex as the Great Lakes is a daunting task. There are numerous physical, chemical, and biological indicators (measures used to characterize the condition of the resource and the progress in protecting, restoring, and conserving it) that have been identified and could be used for such an assessment. However, given limited resources, the IJC must be pragmatic with the selection of indicators and metrics (herein defined as one of multiple quantifiable measures that are associated with each indicator) used for providing a clear message to the public and for assessing progress towards the

[2] International Joint Commission. 1998. The International Joint Commission and the Boundary Waters Treaty of 1909.
[3] Governments of Canada and the United States of America. 2012. Great Lakes Water Quality Agreement. Protocol Amending the Agreement Between Canada and the United States of America on October 16, 1983, and on November 18, 1987.

objectives of the GLWQA. It is equally challenging to effectively engage the public to increase awareness and action around efforts to maintain and restore the health of the Great Lakes. Some may not support monitoring indicators that they do not understand, and so the IJC must ensure effective communication of the indicators monitored. This can be done by measuring the indicators by metrics which are more easily comprehensible and have obvious public value (e.g., fishable, swimmable and drinkable). Also, there are many issues that concern the citizens of the Great Lakes and “compete” for their attention. Therefore, the Parties, given their resource constraints, must also consider their ability to effectively and meaningfully communicate to the public messages that are not only understandable and engaging, but portray, to their best of their ability, current conditions that reflect the state of the Great Lakes. The careful consideration of the communicability of the indicators chosen to monitor and report on is integral to this process.

In 2011, the IJC established a three year priority (2012-2015) to address the challenges covered above by specifically focusing on developing approaches and tools for helping improve the Triennial Assessment of Progress as mandated in the GLWQA. The overall objective of the Assessment of Progress priority is to ensure that the Commission is well placed to fulfil its assessment and reporting responsibilities assigned by the GLWQA. The first major step to achieving this overall objective was establishing workgroups to identify pragmatic sets of ecosystem and human health indicators which clearly and concisely report on the progress of the Parties in their implementation of the Agreement. The workgroups identified 16 ecosystem and five human health indicators that are recommended to be used for assessing progress made toward improving and restoring the health of the Great Lakes.[4]

[4] International Joint Commission, 2015. RCC Subcontract Scope of Work for SPC Communication Indicator Leads.

1.2 Purpose

This report builds upon the work of the IJC's ecosystem indicator workgroup, which was a binational cooperative effort involving over 100 experts from Canada and the United States. The workgroup consisted of members of the Science Advisory Board (SAB), Water Quality Board (WQB), and Health Professional Advisory Board (HPAB), along with support from the State of the Lakes Ecosystem Conference (SOLEC) program of Canada and United States.

The 16 ecosystem indicators identified by this workgroup and associated recommendations are presented in a report issued in 2014 titled, "Great Lakes Ecosystem Indicator Project Report: A Report of the IJC Priority Assessment of Progress towards Restoring the Great Lakes."[5] These 16 ecosystem indicators represent, in the opinion of the workgroup, the "few that tell us the most" and provide good coverage of the GLWQA Objectives and Annexes with the smallest number of indicators possible. However, these 16 indicators are represented by over 40 individual ecological metrics and so several key next steps were identified, including:

- Examine how best to use the 16 ecosystem indicators to report on progress, raise awareness and encourage action
- Identify a small set of indicators and metrics to more effectively communicate with and engage the public
- Gather information to help inform the operationalization of the 16 recommended indicators and associated metrics.

[5] International Joint Commission, 2014. Great Lakes Ecosystem Indicator Project Report.

To help address these recommendations the Commissioners asked the Science Priority Committee (SPC) of the SAB to develop a process for assessing and prioritizing the existing set of 16 Ecosystem Indicators into a smaller set of indicators that can be used to "tell meaningful and compelling stories" to the public about the health and state of the Great Lakes. To address this need, the SPC developed the Communication Indicator Workgroup (CIW) at its inaugural meeting in April 2014. This process and the associated results are the focus of this report.

Goal:

Provide a concise set of indicators and metrics to communicate the condition of the Great Lakes to the public.

Objectives:

1) Develop a framework and methodology for assessing the communicability of ecosystem indicators and metrics.
2) Apply the methodology to assess the current communicability of the 16 ecosystem indicators and associated metrics to identify a smaller subset of indicators and metrics that should be the focus of the IJC's 2017 TAP report.
3) Further interpret the results of the assessment to help inform investments and actions to improve the communicability of the 16 ecosystem indicators and metrics and our ability to effectively communicate progress towards meeting GLWQA objectives in future TAPs.

Major tasks and deliverables of the assessment and prioritization process:

1. Identify a set of four to six ecosystem indicators that can tell meaningful and compelling stories about the health of the Great Lakes and effectively engage the public. An example indicator is "Harmful and Nuisance Algae."

2. For this subset of four to six indicators, compare and rank the component metrics by general assessment of factors that affect our ability to effectively communicate compelling and meaningful information to the public and decision makers. “Excessive algal abundance rating for each lake” is an example of one of the metrics within the Harmful and Nuisance Algae Indicator.
3. Provide additional contextual information on the indicators and metrics that would help the IJC and others make decisions on how best to invest to improve their communicability and our ability to engage the public.

1.3 Scope

This report outlines the background, methodology and results of how the CIW chose which ecological indicators and associated metrics could best be communicated with the public at this time. Included is an overview of the assessment and prioritization process, a discussion of decisions made, and a summary of results and recommendations. The intended outcome of this work is to provide a demonstration on how the IJC will use the ecosystem and human health indicators to assess progress made toward improving the health of the Great Lakes now and in the future.

2 Overview of the entire assessment and prioritization process

Over a 1.5-year timeframe, the workgroup developed a two-phase process to select the ecological indicators, and their relevant associated metrics for the purpose of aiding the IJC with reporting to the public. The workgroup developed a coarse filtering process consisting of four filters against which all 16 indicators were evaluated to identify those with the greatest capacity to tell a compelling story to the general public about the current health of the Great Lakes. The workgroup first ran a pilot session in August 2014, with a slightly larger group of six self-identified interested SPC members to solicit feedback on the indicator-level prioritization process. This session was followed up by a conference call between the workgroup and the larger group to discuss the recommended process and to make any modifications before requesting the entire SPC to partake in the prioritization procedure. The core workgroup then met to discuss the results compiled and summarized by IJC Staff.

The next step in the indicator selection process was to send the results of this prioritization effort to self-selected Research Coordination Committee (RCC) and WQB members for review and comment, particularly regarding the relative logistical challenges of implementing existing or new monitoring programs for these indicators. Based on the results and comments received by the members of the RCC and WQB, in addition to the feedback from the SPC members, it was determined that the selected indicators should represent a comprehensive and balanced list of top six indicators across the biological, physical and chemical categories of indicators in order to provide a balanced coverage of indicators that align with the overall purpose of the GLWQA, "...to restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes." Other key reasons behind this decision include the need to represent the important and informative relations that exist among the indicators across these three categories and to also ensure a blend among the more quickly responding indicators, like those in the chemical category, versus more slowly responding, but more integrative, biological indicators. Once the top six indicators were identified as possessing the greatest communicability in representing the current health of the Great Lakes to the public, the second phase of the prioritization process was initiated. This consisted of developing a set of filters against which the metrics associated with each of the six indicators would be assessed to identify those that would best represent their communications ability (regardless of data availability). Twenty-eight ecological metrics are associated with the top six indicators; these measures were originally generated as the product of a binational cooperative effort and specified in the report of the "IJC Priority Assessment of Progress towards Restoring the Great Lakes" (June 2014). Additional outcomes of the metric prioritization process would also be able to help inform the content of the 2017 TAP report, and help inform investments and actions to improve the communication indicators and metrics (e.g., fill data gaps).

Following the SPC's identification and evaluation of the top six communication indicators, the IJC recommended that aquatic invasive species and chemicals of mutual concern be added to the six indicators selected by the workgroup. After discussion between the workgroup and the SAB Research Coordination Committee (RCC), it was decided that for the other two indicators the RCC and SPC would jointly identify the metrics best positioned to communicate with the public. More specifically, the RCC led the initial data availability assessment, which was completed for the other indicators in October, 2015. That information has been used by a work group consisting of SPC and RCC members to compare and rank the communicability of the metrics for these two indicators. Results for the two additional indicators are reported in a separate report included as Appendix E.

In consultation with interested SPC members, the CIW generated seven filter categories and 17 associated sub-filters in January 2015 that required binary (Yes/No), qualitative and quantitative assessments. Because the metric assessment would be a more involved task that required a certain level of expertise and familiarity with the metrics and their associated data, the CIW was assisted in March 2015 via the RCC-led contractor scoping work. During this data-gathering phase, the CIW had already identified leads for each of the six communication indicators chosen who would ultimately be responsible for interpreting the information gathered by the contractors.

These leads were selected and/or volunteered based on their past experience with the IJC Ecosystem Indicator Report and/or their overall knowledge with respect to the indicator in question. Once the data for the 28 metrics had been compiled by the contractor, these spreadsheets were sent to the leads who were charged with: ranking the metrics associated with their indicator through a predetermined scoring and weighting system developed by the CIW, providing a five to seven page summary of comments for their indicators using a CIW-developed template, and synthesizing the ability of their indicator and metrics to tell a compelling story about the current health and state of the Great Lakes.

The CIW co-chairs assimilated the metric rankings, summarized the written reports, and identified the metrics chosen by the leads to represent their indicator. These results were communally communicated among the leads, and feedback on the metric ranking process was solicited as well as further comments on the prioritization procedure as a whole. Results of the CIW's efforts were presented to the entire SPC at the June 2015 meeting in Windsor, Ontario. Expectations are that the next cycle of indicator-metric selection will be considerably condensed given this report can be used as a guiding template. The current technical report provides (1) a detailed methodology of the assessment of the communicability of the IJC ecosystem indicators and metrics; (2) the main findings of the two-phase process (selected indicators and identified metrics); (3) an evaluation and key observations of the assessment as a whole, and of the indicators and metrics in specifically; and (4) future directions for refinement of the process.

3 Indicator prioritization process methodology

The workgroup first ran a pilot for the indicator prioritization process. This pilot process was completed by the overall workgroup members who then reported challenges and suggested any modifications to the process to the entire SPC. The SPC then discussed these challenges and recommendations and developed the final prioritization process that is described below.

3.1 Prioritization process and definitions

The following description was provided to the SPC on the prioritization process for addressing Objective 1: Indicators:

1. Read the required reading materials
2. Read the definitions of the four filters, provided below, that will be used to conduct independent ranking assessments
3. Assign a score of 1, 3, or 5 to each indicator for each of the four filters. Simply type the values into the appropriate cells (see definitions below)
4. Once completed, save the spreadsheet with a new name, and send it to the secretary of the SPC.

The following filter definitions were used by the SPC to assign a score to each indicator:

Compelling Story: How well does this indicator capture or relate to public interest in terms of assessing if the lakes are fishable, swimmable and/or drinkable?

1. *Not a compelling story,* ***3.*** *Somewhat compelling story,* ***5.*** *Very compelling story*

Visible: How easily can the general public sense changes in this indicator?

1. *Not visible,* ***3.*** *Somewhat visible,* ***5.*** *Very visible*

Easy to understand: How easy is it for the public to understand how this indicator relates to the things they care about and that are related to the GLWQA (fishable, swimmable, drinkable)?

1. *Not easy to understand,* ***3.*** *Somewhat easy to understand,* ***5.*** *Very easy to understand*

Direct measure of lake health: How easy is it to understand how this indicator reflects the actual physical, chemical, and/or biological health of the lakes rather than a source of disturbance/stress?

1. *Very indirect measure,* ***3.*** *Somewhat indirect measure,* ***5.*** *Very direct measure*

3.2 Results

Once the workgroup had completed the pilot process the SPC had the opportunity to comment, critique, and edit the process. The workgroup then asked all of the SPC to complete the process to determine the top indicators for telling meaningful and compelling stories to the public about the health of the Great Lakes. Considering the overall scores shown in Table 1, five out of the top six indicators were biological, only one was physical; while no chemical type indicators rank in the top six. The data availability assessment for Aquatic Invasive Species and Chemicals of

Mutual Concern has been completed by the RCC, and the RCC and SPC has jointly applied the rest of this report's assessment process to these two indicators to compare and rank their respective metrics. More information on this can be found in the following sections of this report.

Table 1 Results of the prioritization process for communication indicators
Biological indicators are highlighted in green, physical in blue, and chemical in brown

Indicators	Type	Total Score	Rank
Harmful and Nuisance Algae	Biological	191	1
Fish Species of Interest	Biological	172	2
Aquatic Invasive Species: Invasion Rates and Impact	Biological	159	3
Water Level	Physical	152	4
Extent, Composition, and Quality of Coastal Wetlands	Biological	142	5
Abundance and Distribution of Fish Eating and Colonial Nesting Birds	Biological	141	6
Nutrients-P Loads and In-Lake Concentrations	Chemical	138	7
PBTs in Biota	Chemical	126	8
Water Temperature	Physical	122	9
Coastal Habitat-Shoreline Alteration Index	Physical	121	10
Chemicals of Mutual Concern in Water	Chemical	119	11
Land Cover Conversion and Fragmentation Index	Physical	114	12
Lower Food Web Productivity/Health	Biological	103	13
Tributary Physical Integrity	Physical	92	14
Contaminants in Groundwater	Chemical	88	15
Atmospheric Deposition of CMCs	Chemical	71	16

The SPC felt that in order to communicate most effectively with the public, it would be better to choose the top two indicators from each of the biological, chemical and physical categories, because the public would better understand physical, chemical and biological integrity than the GLWQA objectives. This decision was also influenced by the IJC's request during the Fall 2014 meeting that stressed the need for *integrated* suites of indicators that help to answer, "How are our programs and policies doing to restore or maintain the health of the Great Lakes?" When the top two indicators of each of the three categories were chosen as seen in Table 2, the top six indicators supported by the SPC to the IJC were finalized. Allowing for physical changes to be monitored as opposed to only biological may allow the IJC to monitor changes in the lakes sooner than the biological and chemical changes, which oftentimes change over longer periods of time. The SPC feels they have equipped the IJC with indicators from each category (indeed, all indicators scored within the top nine) that are focused on assessment, reporting activities, and for communication with the public.

Table 2 Results of the prioritization process when top two indicators from each category are chosen

Indicators	Type	Total Score	Rank (/16)
Harmful and Nuisance Algae	Biological	191	1
Fish Species of Interest	Biological	172	2
Water Level	Physical	152	4
Phosphorus Loads and In-Lake Concentrations	Chemical	138	7
PBTs in Biota	Chemical	126	8
Water Temperature	Physical	122	9

4 Metric Prioritization Process

4.1 Introduction

The purpose of the metric-level prioritization is to provide objective feedback to the IJC to help inform investments into monitoring programs for some or all of the 28 metrics associated with the six communication indicators. A table of indicators with associated metrics is provided in Table 3.

Table 3 List of indicators and associated metrics[6]

Indicator	Metrics	Category
Harmful and Nuisance Algae	1) Harmful Algal blooms rating for each lake	Biological
	2) Nuisance Algal bloom rating for each lake	Biological
	3) Excessive Algal abundance rating for each lake	Biological
Fish Species of Interest	1) Abundance: Cold water, off shore - lake trout and lake whitefish	Biological
	2) Recruitment: Cold water, off shore - lake trout and lake whitefish	Biological
	3) Abundance: Cool water, near shore – walleye	Biological
	4) Recruitment: Cool water, near shore – walleye	Biological
	5) Abundance: Cool water, near shore, rivers, and connecting channels - lake sturgeon	Biological
	6) Recruitment: Cool water, near shore, rivers, and connecting channels -lake sturgeon	Biological
	7) Abundance: Warm water, near shore – northern pike and/or smallmouth bass / largemouth bass	Biological
	8) Recruitment: Warm water, near shore – northern pike and/or smallmouth bass/largemouth bass	Biological
Water Level	1) Long term water level variability	Physical
	2) Timing of seasonal min water level	Physical
	3) Timing of seasonal max water level	Physical
	4) Magnitude of seasonal rise	Physical
	5) Magnitude of seasonal decline	Physical
	6) Lake to lake water level difference	Physical
Water Temperature	1) Annual summer (July-September) surface average temperature for each lake	Physical
	2) Lake water thermal stratification date	Physical
	3) Fall lake water turnover date	Physical
	4) Maximum and average ice concentrations	Physical
Phosphorus Loads and In-Lake Concentration	1) TP Loads from major tributaries	Chemical
	2) DRP Loads from major tributaries	Chemical
	3) TP concentration in lakes	Chemical
	4) DRP concentration in lakes	Chemical
PBTs in Biota	1) PBTs in whole fish	Chemical
	2) PBTs in herring gull eggs	Chemical
	3) PBTs in bald eagles	Chemical

[6] IJC, 2014. Great Lakes Ecosystem Indicator Project Report: A Report of the IJC Priority Assessment of Progress towards Restoring the Great Lakes, pp. 63.

Indicator level analysis can be broad and does not offer enough detail for a comprehensive review so a more thorough metric level analysis was used. That way, the communicability of the indicator could be analyzed on the merits of its associated metrics. The metric level data that was collected from the indicator leads offered a more holistic and objective review of the indicators. To obtain metric level data, the leads of each indicator ranked the component metrics by assessing factors that affect the ability to effectively communicate meaningful information to the public and decision makers. This ranking could then be used as a way to objectively compare and contrast the communicability of an indicator via its associated metrics. The leads also provided additional contextual information on the indicators and metrics that could help the IJC and others make decisions on how best to improve their communicability and our ability to engage the public. This synthesis informed conclusions of which metrics are best suited to be included in the 2017 TAP report. Further, this analysis provided the opportunity to identify data gaps and other limitations associated with these metrics. Therefore, investments and actions to improve our ability to effectively communicate progress with the 28 metrics for future triennial assessments can be targeted at those gaps identified.

4.2 Assessment framework

The working group established seven metric-level filters and sub filters which were binary, qualitative, or quantitative. The definition of each filter is provided in Table 4 Filter Definitions, followed by the purpose of each filter.

Table 4 Filter Definitions

Filter		Definition
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes or No: Do we have comprehensive and evenly distributed data across the entire Great Lakes basin. If No, please describe
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes or No: Are the data for this metric collected with a sample design and sufficient sample size to statistically assess trends for the entire Great Lakes basin?
	Individual lakes	Yes or No: Are the data for this metric collected with a sample design and sufficient sample size to statistically assess trends for each individual lake?
	Subunits of lakes	Yes or No: Are the data for this metric collected with a sample design and sufficient sample size to statistically assess trends for subunits of each lake? (e.g., western, central and eastern basins of Lake Erie)
	Collection locations	Yes or No: Are the data for this metric collected with a sample design and sufficient sample size to statistically assess trends for long term, fixed, monitoring stations/locations?
Regularly monitored	Is metric regularly monitored	Yes or No: Is this metric regularly monitored on a consistent cycle over most or all of the period of record? If No, then briefly describe
	What is the cycle of monitoring?	Provide the temporal cycle over which this metric is monitored (e.g., seasonally, annually, decadal)
Length of monitoring record	What is the period of record?	Provide earliest and most recent year for which data was collected for this metric
	Any major gaps in record?	Yes or No: Are any major gaps in the collection of monitoring data for the metric over the period of record? If Yes, then briefly describe those gaps
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes or No: Have we conducted the necessary science to account for inherent natural variation in this metric across space (different locations) and time?
	Calibrated within and across collection methods	Yes or No: If multiple collection methods are used to collect data for this metric, have efforts been taken to calibrate the differences among these methods?
	Has established endpoints, goals, criteria	Yes or No: Have we established a desired endpoint or range of conditions for this metric? Please describe
Owner and cost	Metric has "owner(s)" (Yes/No)	Yes or No: Are there particular programs or persons that currently lead the collection of data for this metric and have fairly stable funding to continue to provide this monitoring service in the future? Please describe
	Estimated cost	Provide your best estimated annual cost (in dollars) to collect and analyze the data for this metric.
Communicable, interconnected, and useful	Metric can produce data on trends and/or state	Yes or No: Can the data produced be represented as a trend to reflect state of the indicator or provide information such as "Good", "Fair", "Poor" relative to endpoint?
	Linkage / integrity between biological, chemical, physical	Yes or No: Can the metric stand on its own to enable a compelling, integrated story, or does it need to be interlinked with other metrics of this Indicator?
	Utility of collected information	Yes or No: Are there designated program(s) that can make use of this information?

The first filter, *comprehensive data across basin*, assesses if the working group can use the metric to communicate the status and trends at all of the places the metric is relevant or just some of those places. Next, the *rigorously monitored to report statistically meaningful results* filter was applied to assess the specificity of the metrics. As specificity increases, usefulness of the information also increases. For example, communication to a wider audience is possible; specifically about the status and trends in the geography they care about/are responsible for managing. Further, the ability to relate changes in the metric to management actions increases.

Next, the *regularly monitored* filter was used to assess the temporal consistency of the data. As consistency increases, confidence in communicating trends (i.e., no gaps in the record) increases. The *length of monitoring record* filter assesses the overall period of record for each metric; as the period of record increases the ability to identify natural trends increases. This in turn allows for greater confidence in communicating anomalies in trends. *Natural variation, calibration and endpoints* assess the metric's ability to accurately communicate spatial and temporal trends that likely result from disturbances or management actions, rather than trends resulting from natural variation in metric values from place to place or over time. *Owner and costs* assesses the costs which are the necessary compliment to all of the other filters that assess the communication "benefits" of the metrics.

The *interpretable, interconnected, and useful* filter is assessed using three different perspectives. First, if the metric can produce data in trends and/or state. This perspective is used as a general and subjective assessment of more complex filters already stated. Next, the linkage / integrity between biological, chemical, and physical perspective was used to assess if the metric can effectively communicate useful information in the absence of a larger context/set of metrics or indicators. Finally, the utility of the information perspective was used to assess if there is an actual programmatic demand for the metric. This filter can assess both the relative utility of the metric to inform management decisions of existing programs and also if there are critical program gaps. For example, there might not currently be a program that uses and responds to the information a metric provides.

4.3 Compiling data for comparative assessment

The SPC secured a subcontractor through the SAB who assisted the Communication Indicator Workgroup with their metric data gathering process. Through this subcontract, the SPC asked for assistance on identifying, gathering, processing, and integrating Great Lakes basinwide data for the evaluation of data integrity and utility of the six indicators' metrics identified by the SPC. This work interpreted temporal trends and spatial patterns for those indicators that had sufficient existing data and identified data gaps for those indicators which do not have sufficient data.

The contractor compiled data sources for all metrics within each indicator. When data could not be found, a data gap was identified. The contractor used numerous documents and data sources to gather the metric level data to the best of their ability. This data gathering process was more complex than originally thought. For example, some metrics had competing data sources, while some had little to no pre-existing data. Further, data for some metrics were in varying forms which made it difficult to provide consistent information for comparison. Even when data were available, there was no way for the contractor to judge the quality of the data being provided. The contractor also felt that applying a cost associated with the metrics would be a difficult and time consuming task, out of the scope of his/her work. The contractor suggested that moving forward the CIW needs to identify one or two consistent and reliable sources of data to base communicability for each metric. A condensed summary of the findings and suggestions and/or concerns from the contractor is provided in Appendix A. A complete list of the metric-level data gathered by the contractor is provided in Appendix B.

4.4 Developing and implementing metric assessment process

Once the data had been gathered and summarized by the contractor, the CIW designated expert leads to each of the indictors. These leads were responsible for scoring the metrics based on a set of filters that would assess the ability of the metric to describe/analyze the indicator. They then assigned a weight to each of filters, based on their opinion of relevance. The expert leads chosen for each of the indicator are provided in Table 5 below.

Table 5 List of indicator experts which led the metric scoring and weighting process

Indicator	Leads
Harmful and Nuisance Algae	Robert Hecky
Fish Species of Interest	Roger Knight, David Ullrich, Matt Herbert, and Mary Khoury
Water Level	Lauren Fry and Drew Gronewold
Phosphorus Loads and In-Lake Concentrations	David Allan and Carolyn O’Neill
PBTs in Biota	Michael Murray and Dale Phenicie
Water Temperature	Lucinda Johnson and Ed Rutherford

The leads also had the opportunity to describe their interpretation of the various filters, then to weigh the various categories based on their opinion of the importance of informing the public of that indicator, the communicability of that indicator, and finally to determine whether the indicator was interpretable, interconnected, and useful. This process also included the opportunity for experts to identify data gaps when reviewing the available data for an indicator. Absence of data did not indicate absence of concern. Further, this process was intended to identify which metric(s) would be most appropriate for assessing their respective indicator. Tables which synthesize the results from leads can be found in Appendix C. The results of the scoring and weighting of each specific metric by indicator experts can be found in Appendix D.

4.5 Metric-level assessment results and recommendations

4.5.1. Assessment and prioritization of metrics

In order to develop this ranking, the expert leads summed the filter scoring for each metric within the indicator to develop a raw score for each metric. They then applied a weight (1-3) to develop the weighted score for each metric. These weights were applied based on how relevant the leads felt the filter was to the ability to communicate the metric. The weighted score of each metric was then used to rank all metrics within the indicator. A summary of the metric assessment within each indicator is provided below. A table of each metric's score within each filter is also shown, as well as a table which ranks the top metrics within each indicator.

PBTs in Biota

Table 6 Expert lead's filter scoring of each metric within the PBTs in Biota indicator

Metric Category	Filter	PBTs in Whole Fish	PBTs in Herring Gull eggs	PBTs in Bald Eagles	Average Within Filter Across Metrics
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	1	1	0.5	0.83
Rigorously monitored to report statistically meaningful results for	Entire basin Individual lakes Subunits of lakes Collection locations	1	0.88	0.5	0.79
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	1	1	0.75	0.92
Length of monitoring record	What is the period of record? Any major gaps in record?	1	1	1	1.00
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	0.83	0.83	1	0.89
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	1	1	1	1.00
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	0.83	0.83	1	0.89
	Average among filters within metric	0.95	0.93	0.82	0.90

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

As shown in Table 6, PBT in whole fish and herring gull eggs had high scores for all seven metric categories but "PBTs in Whole Fish" was selected as the best metric because they are more rigorously monitored. The data for assessing the metrics within PBTs in biota was generally comprehensive, and of high quality. Within this indicator, the PBTs in whole fish metric is important because fish are of a high trophic level, so contaminants (especially PBTs) can typically be readily measured. Potentially concerning to the public is the impacts of contaminants on fish populations and transfer of contaminants to higher trophic levels, in particular humans. Overall, this indicator is useful to scientists and can be easily interpreted by the public. While this indicator could be coupled with the Chemicals of Emerging Concern indicator, it can stand on its own. Given the potential for spatial differences, it is most appropriate to report on the different metrics by lake given this would presumably be understandable by the public. Regarding temporal scale, it would make sense to highlight changes apparent throughout the period of record, though it would be useful also to report on more recent changes. In order to use this metric, a comprehensive approach to consolidating information on multiple contaminants into a single integrated indicator would be required. In consultation with various experts, leads felt the information gathered is nearly complete.

Table 7 Top ranked metrics within PBTs in Biota indicator

Metric	Raw Score	Weighted Score	Rank
PBTs in whole fish	6.67	9.33	1
PBTs in herring gull eggs	6.54	9.08	2
PBTs in bald eagles	5.75	8.25	3

Water Temperature

Table 8 Expert lead's filter scoring of each metric within the Water Temperature indicator

Metric: Category	Filter	Annual summer (July-September) surface average temperature for each lake	Lake water thermal stratification date	Fall lake water turnover date	Maximum and average ice concentrations	Average Within Filter Across Metrics
Data across basin	Is there comprehensive coverage of data for this metric?	1	1	1	1	1
Rigorously monitored to report statistically meaningful results	Entire basin Individual lakes Subunits of lakes Collection locations	0.5	0.5	0.5	0.88	0.59
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	0.75	0.75	0.75	1	0.81
Length of monitoring record	What is the period of record? Any major gaps in record?	0.5	0.5	0.25	1	0.56
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	1	0.67	0.67	1	0.83
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	1	1	1	1	1
Interpretable interconnected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	1	1	1	1	1
	Average among filters within metric	0.82	0.77	0.74	0.98	0.83

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

The Water Temperature indicator data was extensive and easily acquired. “Maximum and average ice concentrations“ scored highest for the majority of assessment categories, most notably for the length of its monitoring record. While the data were reasonably good, they were acquired using remote sensing and observers, so cloud cover may impede its usefulness. This data is useful to many different managers and researchers, can easily be interpreted by the public, and is connected to several indicators but can stand on its own. In order to use the metric for communication with the public, narratives based on visual changes can be made. For example, what is the impact of low ice cover on lake levels or on fishing? Narratives based on long-term temporal scales could also be made. A key strength of this indicator is that its data is already being collected, and so it can easily become an operational metric. In consultation with various experts, the leads felt that the information gathered is largely complete.

Table 9 Top ranked metrics within Water Temperature indicator

Metric	**Raw Score**	**Weighted Score**	**Rank**
Max ice cover	6.88	9.88	1
Water temp	5.75	7.75	2
Thermal stratification	5.42	7.67	3
Fall turnover	5.17	7.17	4

Water Levels

Table 10 Expert lead's filter scoring of each metric within the Water Levels indicator

Metric: Category	Filter	Long term water level variability	Timing of Seasonal Min Water Level	Timing of Seasonal Max Water Level	Magnitude of seasonal rise	Magnitude of seasonal decline	Lake to lake water level difference	Average Within Filter Across Metrics
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	1	1	1	1	1	1	**1**
Rigorously monitored to report statistically meaningful results for	Entire basin Individual lakes Subunits of lakes Collection locations	0.75	0.75	0.75	0.75	0.75	0.75	**0.75**
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	1	1	1	1	1	1	**1**
Length of monitoring record	What is the period of record? Any major gaps in record?	1	1	1	1	1	1	**1**
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	0.83	0.83	0.83	0.83	0.83	0.83	**0.83**
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	1	1	1	1	1	1	**1**
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	0.83	0.83	0.83	0.83	0.83	0.83	**0.83**
	Average among filters within metric	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

All metrics within this indicator received the same score as their assessment was based on the same data. However, the leads found that the “Long-term Water Level Variability” metric was most suitable to communicate the water level indicator. Great Lakes water level data represent one of the most consistent and long-term records of the entire Great Lakes system, with at least one gauging station on each lake reporting continuous daily or monthly water level measurements going back to at least 1860. For much of this period, multiple gauges across each lake are used to compute a lake-wide average. While relatively straightforward, this metric may take time for many users to fully understand. This metric is particularly useful to other programs because it represents an aspect of water levels that typically *directly* impact ecological endpoints (such as wetland migration). This is opposed to other aspects of water level change (such as spring rise) that are affected by climatological drivers (e.g., precipitation).

This data could be communicated via graphical summary of the long-term variability. It would be helpful to link presentations on this metric with comparable presentations on wetland habitats and wetland migration, particularly on Lake Ontario (following water level regulation) but also on other coastal ecosystems that have been impacted by the reduced variability (i.e., on Michigan-Huron) between 1998 and 2014. In order to do this, the National Oceanic and Atmospheric Administration (NOAA) or US Army Corps of Engineers (USACE) could be requested to routinely compute this metric and communicate it through an existing public web-based outlet (such as the water levels dashboard, or the USACE water levels bulletin).

Table 11 Top ranked metrics within Water Temperature indicator

Metric	Raw Score	Weighted Score
All metrics same score	6.4	6.4

Fish Species of Interest

Table 12 Expert lead's filter scoring of each metric within the Fish Species of Interest indicator

Metric: Category	Filter	Lake Trout/ Whitefish Abundance	Lake Trout/ Whitefish Recruitment	Walleye Abundance	Walleye Recruitment	Lake Sturgeon Abundance	Lake Sturgeon Recruitment	Northern Pike/ SMB/ LMB Abundance	Northern Pike/ SMB/ LMB Recruitment	Average Within Filter Across Metrics
Data across basin	Is there comprehensive coverage of data for this metric?	1.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.25
Rigorously monitored to report statistically meaningful results for	Entire basin Individual lakes Subunits of lakes Collection locations	1.00	1.00	0.63	0.75	0.88	0.00	0.25	0.13	0.58
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	1.00	1.00	1.00	1.00	0.50	0.25	0.25	0.50	0.69
Length of monitoring record	What is the period of record? Any major gaps in record?	1.00	1.00	1.00	0.25	0.25	0.25	0.00	0.00	0.47
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	0.83	0.83	0.67	0.67	0.33	0.17	0.00	0.00	0.44
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	0.50	0.50	0.50	0.50	0.75	0.50	0.25	0.25	0.47
Interpretable inter-connected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	0.83	0.83	1.00	1.00	1.00	0.67	0.83	0.50	0.83
	Average among filters within metric	0.88	0.81	0.68	0.60	0.60	0.26	0.23	0.20	0.53

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

The highest ranking metric for Fish Species of Interest was "lake trout/lake whitefish adult abundance." This is strongly in line with the many lake committees who identify lake trout in their fish community objectives for deep cold-water habitats. This ranking was based on generally available data, which was of highest quality in the upper lakes, with comprehensive coverage basin-wide. In order to pursue this metric, fishery manager (Great Lakes Fishery Commission [GLFC] Lake Committee) participation would be required. The strength of this metric is its ability to reflect multiple stressors in different ways. While it is useful as a stand-alone indicator of oligotrophic habitats, it is more powerful if used with other indicators.

If there is to be only one metric used throughout the lakes, it is recommended to measure lake trout/lake whitefish adult abundance. Trends in both species should be used for each lake and may differ between these species within each lake. Alternatively, consideration of areas such as restoration of Area of Concern (AOC) fish habitat, coastal wetlands, and tributary spawning habitats should drive what indicators are used to evaluate progress, rather identifying a suite of generic fish indicators to apply across the lakes. In any case, such a decision could be deferred to the lake committees to help select which species to use for each lake or focus area, the spatial and temporal scales, and to identify the relevant criteria for indicator selection.

In order to operationalize this metric, data and targets that are already collected and established by fisheries management agencies, in connection with partners such as The Nature Conservancy, can be used. Consultation with the GLFC Lake Committees is critically important to ensure consistency in public messages from the IJC and fisheries managers for this metric. Further, the public should be well informed about exactly what can be done through management actions to effectively address impacts from anthropogenic sources of stress, what is being planned in the way of actions, and what outcomes are expected to occur. These items are especially important to determine short and long-term progress to sustain public support. However, caution should be used when interpreting fish indicators that can reflect multiple stresses and different remedial management actions. For example, signs of recovery of lake trout in Lake Huron appear to be related to a major decline in non-indigenous alewife more so than any human-induced improvements to the system. The alewife decline is not an expected outcome from a deliberate management action but rather a "natural" event with unknown causal mechanisms.

Table 13 Top ranked metrics within Fish Species of Interest indicator

Metric	Raw Score	Weighted Score	Rank
Lake Trout/Whitefish Abundance	6.2	9.0	1
Lake Trout/Whitefish Recruitment	5.7	8.5	2
Walleye Abundance	4.8	7.5	3
Walleye Recruitment	4.2	6.8	4
Lake Sturgeon Abundance	4.2	5.5	5
Lake Sturgeon Recruitment	1.8	2.5	6
Northern Pike/SMB/LMB Abundance	1.4	2.4	7
Pike/SMB/LMB Recruitment	1.6	2.1	8

Harmful and Nuisance Algal Blooms

Table 14 Expert lead's filter scoring of each metric within the Harmful and Nuisance Algal Blooms indicator

Metric: Category	Filter	Harmful Algal Bloom Rating	Nuisance Algal Bloom Rating	Excess Algal Abundance Rating	Average Within Filter Across Metrics
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	0	1	0	0.33
Rigorously monitored to report statistically meaningful results for	Entire basin Individual lakes Subunits of lakes Collection locations	0	0.5	0.13	0.21
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	0	0.5	0.25	0.25
Length of monitoring record	What is the period of record? Any major gaps in record?	0.25	0.75	0.25	0.42
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	0.33	0.67	0.17	0.39
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	1	0.75	0.75	0.83
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	0.33	0.83	0.17	0.44
	Average among filter within metric	0.27	0.71	0.24	0.41

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

The highest ranking metric for the HABs indicator was nuisance algal blooms (planktonic blooms). Assessment for this metric was based on Meris and Modis satellite imagery data that have sufficient reliability in time and space to generate annual assessments of bloom frequency and extent. These data are sufficient for identifying bloom conditions, somewhat less precise and accurate at lower (non-bloom) chlorophyll concentrations (< 5 µg chlorophyll L-1), although they are still able to provide useful information on monitoring chlorophyll in oligotrophic conditions which are of less concern for this indicator. Applicability has been demonstrated for western Lake Erie with highest quality imagery (with good spectral resolution) that extends at least to the year 2000. However, chlorophyll concentration in surface waters from satellite imagery algorithms can be considered an extension in time and space of the binational shipboard monitoring program which has historically been the basis for evaluating effectiveness of nutrient management actions and which extends back to the early 1980s. Satellite imagery is continuously archived by NASA and other space agencies making it freely available for development of future applications and retrospective analysis. Software for mapping chlorophyll is well developed and publicly available. NOAA has developed a satellite imagery based bloom forecasting system for western Lake Erie which can be adopted to provide annual assessments for that high priority region; but technology can be applied to other problematic area such as Saginaw Bay.

Satellite imagery can also give surface water temperature which is important to timing of blooms and make the occurrence of blooms more likely under climate change. Planktonic blooms and surface chlorophyll in general are a consequence of, and a clear sign of, nutrient over-enrichment which is of primary concern under the GLWQA. All nutrient management programs strive to reduce excessive planktonic algal growth. Satellite imagery cannot predict toxicity of a cyanobacterial bloom but toxic events are much less probable without occurrence of a cyanobacterial surface bloom which can be observed. Also, surface chlorophyll and blooms will not address or identify noxious benthic plant growth which is largely the result of increasing water transparency and local enrichment from anthropogenic sources or dreissenid recycling of phosphorus. Local monitoring programs will be necessary to follow the highly seasonal (and high inter-annual variability) waxing and waning of excessive plant growth such as Cladophora. This metric could be based on an annual assessment of the length duration and maximum extent of mid- to late-summer blooms. This metric can stand independently but could be related to basinwide monitoring of chlorophyll and also related to nutrient loading and concentrations which are the ultimate cause of blooms.

Table 15 Top ranked metrics within Harmful and Nuisance Algal Blooms Indicator

Metric	Raw Score	Weighted Score	Rank
Nuisance algal bloom	5.0	7.3	1
Harmful algal bloom	1.9	2.6	2
Excess algal abundance	1.7	2.0	3

Nutrients-P Loads and In-Lake Concentrations

Table 16 Expert lead's filter scoring of each metric within the Phosphorus Loads and In-Lake Concentrations indicator

Metric: Category	Filter	TP Loads from Major Tributaries	DRP Loads from Major Tributaries	TP Concentration In Lakes	DRP Concentration In Lakes	Average Within Filter Across Metrics
Data across basin	Is there comprehensive coverage of data for this metric?	1	0	1	0.5	0.63
Rigorously monitored to report statistically meaningful results for	Entire basin Individual lakes Subunits of lakes Collection locations	1	0.38	1	0.67	0.76
Regularly monitored	Is metric regularly monitored What is the cycle of monitoring?	0.75	0.75	1	0.75	0.81
Length of monitoring record	What is the period of record? Any major gaps in record?	0.75	0.75	1	0.75	0.81
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals, criteria	0.67	0.5	0.83	0.83	0.71
Owner and cost	Metric has "owner(s)" (yes/no) Estimated cost	0.75	0.5	1	1	0.81
Interpretable inter-connected, and useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	0.83	0.67	1	0	0.63
	Average among filter within metric	0.82	0.51	0.98	0.64	0.74

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

“TP concentration in Lakes” is considered to be the metric that would be most easily understood by a lay audience, followed by TP loads from major tributaries. However, leads suggest that all four metrics not be used when telling the story of this indicator to the uninformed public, as it is expected that two measures of phosphorous will cause confusion. Communicating tributary loads/concentrations would require an explanation and understanding of how tributaries contribute to in-lake phosphorous loads/ concentrations. However, it is acknowledged that tributary measurements would be of interest to particular sectors/stakeholders (e.g., municipalities, the agricultural sector). It is suggested that two sets of communications metrics may therefore be appropriate – one set aimed at the lay public and one aimed at the informed public/stakeholders.

Nutrients cannot be a standalone indicator of the health of the Great Lakes, because the impact that phosphorous loads and concentrations will have on the health of the Great Lakes is dependent upon many other factors, such as water temperature, and nutrient cycling by invasive species. With regard to phosphorous concentrations, the hydrograph, stream flow, and microclimate (wind, precipitation events) all play a role. Therefore, it is suggested that harmful and nuisance algae and water temperature would always need to be communicated in concert with the nutrients indicator in order to properly communicate the impact of the nutrients indicator on the Great Lakes. In addition, it is recommended that the nutrients indicator cannot effectively convey the health of the lakes without also considering the invasive species that cycle and retain nutrients in the lakes. For example, communicating the total P concentrations in lakes will not explain the growth of Cladophora that can occur in coastal zones despite low offshore P concentrations due to the nearshore shunt that has been caused by the establishment of dreissenid mussels (Hecky et al, 2004).[7] It is noted that the indicators chosen for this exercise can, when conveyed in concert, explain the development of harmful algal blooms but cannot explain the development of Cladophora.

While often the focus of research for nutrients in the lakes is on 'too many nutrients,' but many regions of the lakes are suffering from "too few nutrients" due to mussels. Therefore, an effort to incorporate a greater understanding of nutrients' positive role in fueling ecosystem productivity would be ideal. It is recommended that NOAA's Experimental Lake Erie Harmful Algal Bloom Bulletins could be utilized to communicate the nutrients metric, as nutrients are of particular concern for Lake Erie. NOAA's bulletins include water temperature data and map the development of HABs using measurements of cyanobacteria concentrations in the water. Adding nutrients concentrations/loads to the data already presented would assist in communicating how nutrients can result in HABs in conjunction with other factors, such as water temperature and wind. It is noted that, regardless of the nutrient metric(s) chosen, the timing of the annual measurements used would require consideration given the intra-annual variation of TP/DRP loads/concentrations in lakes and tributaries.

Table 17 Top ranked metrics within Harmful and Nutrients-P Loads and In-Lake Concentrations indicator

Metric	Rank†
DRP loads from major tributaries	1
DRP concentration in lakes	2*
TP loads from major tributaries	3
TP concentration in lakes	4

* While leads were in agreement of rank 1, one lead felt rank 2 should go to DRP in rivers ahead of DRP in lakes on basis of recent findings western Lake Erie.

[7] Hecky, R.E., Smith, R.E.H., Barton, D.R., Guildford, S.J., Taylor, W.D., Charlton, M.N., Howell, T., 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Can. J. Fish. Aquat. Sci. 61, 1285–1293.

†Highest rank in this case = highest score.

4.5.2. Recommended metrics to include in 2017 TAP Report

The selected metrics per indicator are shown in Table 18. These represent the metrics the leads felt were relatively best at communicating the state of the Great Lakes, based off of pre-selected indicators chosen for their ability to tell compelling stories (i.e., be reportable and engaging). The only change was after the analysis the authors added walleye abundance to the second metric for Lake Erie which has a different fish community than the other four lakes (and was additionally ranked highest following lake trout / whitefish metrics).

Table 18 Selected communication indicators and their highest-scoring 'communicability' metrics

Category	Indicator	Metric
Biological	Harmful and Nuisance Algae	Nuisance algal blooms
Biological	Fish Species of Interest	Lake trout/lake whitefish adult abundance, (Walleye abundance for Lake Erie)
Chemical	Phosphorus Loads and In-Lake Concentrations	TP concentration in lakes
Chemical	PBTs in Biota	PBTs in Whole Fish
Physical	Water Temperature	Maximum Ice Cover
Physical	Water Level	Long-term water level variability

An overall assessment of the highest ranked-metrics' communicability, demonstrated in Table 19, reveals there remain some moderate issues that must still be addressed. For instance, rigorous and/or regular monitoring is deficient for the top-ranked water-level, water temperature and HAB metrics; having an owner and estimated cost remains a challenge for the highest ranked

Fish Species of Interest metric; and the chemical-indicator metrics suffer from having a lack of natural variation, calibration and endpoints.

Table 19 Communicability of the top-ranked metrics

Category	Metric	Average "Communicability" Score (0 to 1)	Highest-scored Filter Category	Lowest-scored Filter Category
Biological	Nuisance algal blooms	**0.71**	• Comprehensive data across basin	• Rigorously & regularly monitored
Biological	Lake trout/lake whitefish adult abundance	**0.88**	• Comprehensive data across basin • Rigorously & Regularly monitored • Length of record	Owner and cost
Chemical	TP concentration in lakes	**0.98**	• All categories same score except:	• Natural variation, calibration and endpoints
Chemical	PBTs in Whole Fish	**0.95**	• All categories same score	• Natural variation, calibration and endpoints • Interpretable, interconnected and useful
Physical	Maximum Ice Cover	**0.98**	• All categories same score	• Rigorously monitored
Physical	All Metrics	**0.92**	• Comprehensive data across basin • Regularly monitored • Length of record • Owner and cost	• Rigorously monitored

In the face of much uncertainty and data limitations, at this time Table 19 reflects the best set of indicators and metrics that should be used for communicating with the public. In addition, our workgroup believed that in addition to providing this recommendation, it is equally important to provide the IJC with information they can use to make more informed decisions about which metrics to include in future assessment of progress reports and where investments are needed to improve the communicability of the metrics and indicators. The workgroup also recommends that the results from this assessment of communicability of the ecosystem indicators and metrics should be combined with other information and recommendations provided by other IJC (e.g., Program and Human Health Indicator), Annex (e.g., Annex 10 Data Management and Sharing) and SPC (e.g., Information Coordination and Flow) work groups. The work of these various groups is complimentary and should be examined collectively to inform decisions on the content of the 2017 Triennial Report and recommended investments to improve our monitoring programs and the resulting indicators and information that can be included in future reports.

4.6 Metric ranking data gaps and limitations

From a quantitative perspective, Table 20 synthesizes the overall score assigned by the leads for each metric which was used to come to a decision regarding the most suitable one(s). These summarized scores indicate there is a continuum of minor to severe issues with communicability across all of the metrics. In fact, all of the metrics had some issues that affect their communicability, but fortunately over half of the metrics had only minor issues. There are a range of investments needed to improve all of the metrics, with the most pressing requirements for the metrics associated with the nutrients, fish species of interest, and HABs, which all have severe issues with communicability as shown in Table 19.

When soliciting feedback, the most consistently raised issue amongst the leads of the metric prioritization process was the inability to report statistically meaningful results for individual lakes or sub-units of the lakes. Not having trend data at this finer spatial grain significantly hinders our ability to relate any changes in these metrics and indicators to associated changes in disturbance, human health and program indicators. This was seen as a major shortcoming by the work group, and hence could affect the reporting of certain metrics to be used as communicators of trends. A reason given for this limitation is that changes at larger spatial scales occur at longer time scales, and these changes are additionally affected by distant and diffuse human disturbances, conservation actions and regulations; therefore impacts are a challenge to quantify. Additionally, most metrics had been calibrated to account for natural variation and different collection methods. However, many fewer had established criteria or goals to measure against.

Table 20 Combined results of average metric scoring and weighting by experts among all indicators

	Physical		Chemical		Biological	
Average "Communicability" Score (Range from 0 to 1)	**Water Level**	**Water Temperature**	**PBTs in Biota**	**Nutrients**	**Fish Species of Interest**	**HABs**
1	None	None	None	None	None	None
0.76 to 0.99	Long term water level variability Timing of seasonal min water level Timing of seasonal max water level Magnitude of seasonal rise Magnitude of seasonal Lake to lake water level	Maximum and average ice concentrations Annual summer (July-September) surface average temperature for each lake Lake water thermal stratification date	PBTs in whole fish PBTs in herring gull eggs PBTs in bald eagles	TP loads from major tributaries TP concentration in lakes	Lake trout/whitefish abundance Lake trout/whitefish recruitment	None
0.51 to 0.75	None	Fall lake water turnover date	None	DRP loads from major tributaries DRP concentration in lakes	Walleye abundance Walleye recruitment Lake sturgeon abundance	Nuisance algal bloom rating
0.26 to 0.50	None	None	None	None	Lake sturgeon recruitment	Harmful algal bloom rating
Less than 0.26	None	None	None	None	Northern pike/SMB/LMB abundance Northern pike/SMB/LMB recruitment	Excess algal abundance rating

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

Alternatively, most metrics did have “owners”; i.e., programs or persons that currently lead the collection of data for this metric and had fairly stable funding to continue to provide monitoring services in the future. One exception was for certain fish species/guilds that lacked extensive monitoring of abundance and recruitment parameters. It is recommended that Lake Committees (e.g., fish-management communities) should be consulted and approached in the future for evaluation of the communicability of any fish metrics. Lastly, a key point discussed was the ability and necessity of the chosen metrics to be used in isolation of others. With the exception of nutrient-loads metrics, most others were valuable as stand-alone, but the strength of the usefulness in communicating the state of the Great Lakes rested in their ability to integrate across the bio-physical and chemical realms. It was opined that communicating the status of lake health in the most integrative, yet economized way is paramount, and again, should be informed by and work in conjunction with other work groups (IJC, Annex, SAB).

To summarize, based on the quantitative evaluation of this indicator/metric prioritization process, in combination with feedback and reports from the CIW members, leads, and the wider SPC, the CIW believes metric-level assessment for communicability should be considered using four distinct categories of factors: data availability, science and policy, program operations, and general ability to communicate. To operate, broader input is necessary from multiple stakeholders, monitoring community, scientists, policy makers, and the public.

5 Synthesis and recommendations

In this section a brief synthesis of the main findings of our indicator assessment and prioritization process is provided. Recommendations for improving the communicability of specific indicators and metrics are also provided. Finally, recommendations on how the IJC could significantly improve this assessment process in the future is offered, could it be decided to pursue and implement a prioritization process with each new priority cycle. Collectively, our work group firmly believes that taking steps to address these recommendations will lead to significant improvements to the triennial reports and our ability to tell meaningful and compelling stories to the public and Great Lakes decision makers.

5.1 General findings

The six best indicators to be used for communicability are identified in Table 18. These are HABS: Nuisance algal blooms (planktonic blooms); lake trout/lake whitefish adult abundance (walleye for Lake Erie); TP concentration in lakes; PBTs in whole fish; Maximum ice cover; and Long-term water level variability. There is a lot of uncertainty and data gaps so the IJC should revisit these decisions as more information becomes available.

In terms of comparing amongst the selected metrics, the highest scores for communicability were for the metrics associated with the physical indicators followed by those for the chemical indicators and the lowest scores were found for the metrics associated with the biological indicators. This is largely due to the overall ease in monitoring, collecting, and analyzing of water levels and temperatures, and to a lesser extent, PBTs and nutrients within and across basins. While biological *indicators* can often tell compelling stories about the nature and state of the Great Lakes, they suffer more from having higher associated monitoring costs and thus less and more sparsely available data. They also suffer from having a high number of groups that collect these data (i.e., high number of owners) which makes data integration more challenging.

5.2 Improving the communicability of metrics and indicators

Future directions to aid in improving the overall "communicability" of metrics and to reflect the current and relevant pressures affecting the Great Lakes are provided.

5.2.1. Refining spatial scale of monitoring

Appropriate combinations of each of the metrics (and therefore indicators) should be used to construct the state of play on a lake-by-lake basis. Integrating them at the basin level will be helpful given the uniqueness of each lake. The premium in reporting could be placed on the combinations of indicators (and metrics) that help inform the public about what is going on. In order to do this, it may be necessary to calibrate across different gears to enable integration of multiple datasets. For example, how do ice cover and water temperature link to phosphorous loadings, HABs and walleye abundance in Lake Erie? At once physical, chemical and biological integrity metrics can be used to help explain how climate change and nutrient inputs are stacking up to cause algal blooms, etc.

Further, it is important to make sure stakeholders and the public understand at what spatial and time scales they are relevant and can provide meaningful information on trends. For example, avoid applying generic fish indicators across all lakes for a fish species of interest. Instead, lake specific or basinwide spatial scale may be necessary.

5.2.2. Considerations when scoring

A future priority for improving the communicability of metrics and indicators would be to keep them simple and use general labels to communicate scores relative to targets, but to nonetheless still base them on quantitative scoring.

The ability to obtain a "score," however, depends on the quality and quantity of data available now and in the future. The operationalization cost of the indicators and their metrics proved to be a bit of a stumbling block for the leads and experts in terms of determining the communicability of the indicator and associated metrics. What is required, therefore, is an investment of effort into being able to calculate the cost of collecting the data for each metric and indicator. That is the only way one may be able to truly assess the relative costs and benefits of investing in the continued monitoring and improvement of monitoring data for these and other indicators. For instance, if one wanted to increase monitoring efforts to be able to report at subunits of the lakes, how much would that cost for each metric/indicator? Therefore, establishing specific owners and sustainable funding streams to support monitoring is integral.

5.2.3. Expanding the temporal and spatial extent of monitoring

There is the need to identify short-term targets and actions as priorities (e.g., for the 5-yr Lakewide Management Plan [LAMP] cycles) in each lake, and having adequate indicators to track short-term progress toward targets. Lake partnerships need to at least make meaningful (measureable) progress toward short term targets to keep managers and stakeholders with resources engaged. These indicators may be more meaningful for evaluation at basinwide 10-year scales, rather than at lake-specific five-year scales, where inherent variation and linkage to multiple stresses may make them insensitive to showing changes (progress or lack thereof). In order to define the spatial and temporal extent required, specific endpoints/goals for each metric and indicator to measure progress against should be established. It will also be important to account for natural variation to ensure effective detection of impacts from human disturbances and our management actions.

5.2.4. Improving the overall assessment of communicability process

The work group believes that the IJC should continually assess our ability to effectively communicate to the public and Great Lakes decision makers. As such, it is recommended the IJC establish a regular cycle for repeating the communicability assessment covered in this report. A six to nine-year assessment cycle that aligns with the triennial reports would be a reasonable cycle for repeating this assessment process to determine if progress is made towards addressing the recommendations made in this and future reports. Further, the IJC should take steps to improve this assessment process. First, a slight regrouping of the filters used in the metric-level assessment into four distinct categories of factors that affect communicability is recommended: data availability, science and policy, program operations, and general ability to communicate. The following list provides the specific filters that would fall within each of these general categories:

1. Data availability
    a. Comprehensive data across basin
    b. Rigorously monitored to report statistically meaningful results for individual lakes, subunits of lakes, collection sites
    c. Regularly monitored
    d. Length of monitoring record
2. Science and policy
    a. Calibrated to account for natural variation across space and time
    b. Calibrated within and across collection methods
    c. Has established endpoints, goals, criteria
3. Program operations
    a. Regularly monitored
    b. Metric has an owner

    c. Data/info is used by a program
    d. Monitoring costs
4. General ability to communicate/tell a story
    a. Metric can produce data on trends and/or state
    b. Linkage /integrity between biological, chemical, physical

Next, the IJC should establish a more formal process for assessing the communicability of indicators and metrics in the future that allows for soliciting input from a broader set of stakeholders. The four general categories of the metric-level filters listed above require input from multiple stakeholders including the monitoring community, scientists, program administrators, and policy makers. This current assessment was largely conducted by scientists and the monitoring community. Thus the CIW believes that future assessments need to get broader input particularly from program administrators and policy makers. Furthermore, given the fact that the monitoring data are collected and the triennial reports are produced in large part to communicate with the public, the IJC should develop a process to efficiently and effectively solicit input from interested public stakeholders.

As mentioned previously, assessing cost must be a priority. The fact that the CIW cannot currently quantify the costs to collect these monitoring data is a major concern of the work group. Therefore, the IJC should put in place processes that allow for the accurate calculation of monitoring costs for each metric and indicator so they can assess both costs and benefits in our decisions on where to invest to improve our monitoring programs and the overall quality of the triennial reports.

It is recommended that this process be expanded to more accurately assess our ability to effectively communicate with the public and inform Great Lakes decision makers. More specifically, this process should be expanded to include all 16 ecosystem indicators. The SAB RCC has assessed the data availability for all 16 ecosystem indicators. The RCC is also in the process of identifying future improvements on the Great Lakes indicators which build on the Parties' State of the Great Lakes indicator suite. This will allow for a better understanding of the progress made towards reaching the objectives of the GLWQA. The goal of this effort is to provide input about how to optimize investment effectiveness by maximizing the capability of assessment of progress while keeping cost of monitoring programs in mind. Moving forward, it is important a standard process be used in future assessments which answers and communicates the following to a variety of audiences, "Are our management programs and actions adequately addressing the threats and stressors impacting the health of Great Lakes and leading to our desired ecological and socioeconomic outcomes?"

Only by answering this question can these types of reviews truly tell compelling stories and provide decision makers with the information they need to adaptively manage their respective programs to maintain and restore the health of the Great Lakes. To do this, it is required that the IJC and others takes steps to identify and ensure monitoring of not just ecosystem indicators, but rather suites of indicators, from threats and stressors to management programs and activities to ecosystem and socioeconomic health. In 2014, HPAB recommended five human health hazard and exposure indicators in its report to the IJC, "Recommended Human Health Indicators for Assessment of Progress on the Great Lakes Water Quality Agreement."[8] The indicators were selected due to their alignment with pathways of risk for human users of the Great Lakes

[8] Can be accessed at http://ijc.org/files/tinymce/uploaded/HPAB/Recommended-Human-Health_Indicators-June2014.pdf

resources and general objectives of the LWQA. The HPAB report noted differences between HPAB's indicators and SOLEC indicators, and included a series of recommendations.

It is recommended that a true assessment of communicability must extend beyond the collection of the right data (i.e., suites of indicators and metrics) to include an assessment of how effectively the management and delivery of this information is to their intended audiences. Fortunately, the SPC recently established an Information Coordination and Flow (ICF) work group that has a goal of identifying and assessing programs and platforms that collect, deliver and use data and information in the Great Lakes basin to support water quality management and policy decisions. The information provided by ICF Work Group will include short and long-term recommendations for improving the data and information flow assessment process to assess gaps and barriers in the collection, management and delivery of data and information which supports the management and policy decisions needed to achieve the objectives of the GLWQA.

This information flow assessment will focus on two selected GLWQA objectives and assess the flow and information across the following five categories of indicators:

- Socioeconomic conditions
- Biological conditions
- Habitat conditions
- Human stressor/disturbances
- Management practices and activities

This assessment will allow the CIW to determine if decision makers are provided with complete stories that answer, "Are our management programs and actions adequately addressing the threats and stressors impacting the health of Great Lakes and leading to our desired ecological and socioeconomic outcomes?" Decision makers, from local to basinwide scales, need this full suite of information to make well informed decisions. It provides the full context needed to assess if our programs are working effectively and to discover reasons why they may not be.

Appendix A: Summary of Metric Data Provided by Contractor

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

There is some disagreement about the length of record for all metrics for this indicator. The contractor suggests using the longest possible record, i.e., 1860s to present, to help observe and identify long-term trends. Collection methods are consistent and long-term data are available for metrics one through three, and six. In metrics four and five data is most likely sufficient but how ‘spring rise’ and ‘fall decline’ will be quantified needs to be specified. The contractor questioned if these metrics be calculated from monthly means or if they require daily lake levels.

Metric 1: Long-term water level variability was based on assessing trends in "rolling" 5- and 30-year standard deviation of monthly mean water levels over the period of record for each of the Great Lakes.

Metric 2: Timing of seasonal min water level was measured based on assessing changes over time in the month in which the seasonal water level minimum occurs.

Metric 3: Timing of seasonal min water level was measured based on assessing changes over time in the month in which the seasonal water level maximum occurs.

Metric 4: Magnitude of seasonal rise was measured based on assessing trends over time in the magnitude of spring rise. Data is most likely sufficient but exactly how will be quantified needs to be specified.

Metric 5: Magnitude of seasonal decline is measured based on assessing trends over time in the magnitude of fall decline.

Metric 6: Lake to lake water level is measured based on assessing long-term trends in the difference between the monthly mean water level for each lake and the monthly mean water level for the downstream lake.

Water Temperature

The water temperature indicator description indicates analyses at lake spatial extent but the contractor highly recommended additional analyses at the lake sub basin extent for all metrics.

Metric 1: Annual summer (July-September) surface average temperature for each lake has recommends using Great Lakes Surface Environmental Analysis (GLSEA) Sea Surface Temperature (SST) modelled temperature to allow a more appropriate spatial unit for trend analyses.

Metric 2: Lake water thermal stratification date (as defined by surface water reaching its temperature of maximum density in spring/summer (3.98°C)). The timing of spring stratification can be estimated using direct measurement of surface water temperature at buoys or with output of the GLSEA SST models.

The contractor had the following questions for metrics two and three:

- What is the technical definition of stratification or fall mixing?
- E.g., stratification could be defined with different criteria: When stratification begins? When stratification is maintained and does not revert back to mixing? When the entire lake is stratified or when the edges begin to stratify?
- How should we define the first and last day of ice cover since low ice cover estimates are less reliable? We suggest using a greater than ten percent threshold to identify ice on and ice off dates.

Metric 3: Fall lake water turnover date (as defined by surface water reaching its temperature of maximum density in fall/winter (3.98°C)). The timing of fall lake turnover can be estimated using direct measurement of surface water temperature at buoys or with output of the GLSEA SST models.

Metric 4: Maximum and average ice concentrations has readily available ice cover data and can be calculated and examined for temporal trends. The indicator summary table specifies the seasonal average ice cover is the sum of the daily lake-averaged ice cover over a winter divided by 182 (the number of days between 1 December to the following 31 May), but in the next sentence includes "the seasonal average ice cover is calculated for days when the lake-averaged ice cover was greater than or equal to five percent." A reasonable interpretation of the discrepancies in the text would be to use the 182 day season but include the daily ice values only when a grid has an ice cover greater than or equal to five percent (or ten percent). The contractor was concerned with five percent threshold because ten percent is the smallest percent ice cover for each ice chart and ice less than ten percent is considered the boundary between ice and open water. The contract questioned the justification for the five percent threshold.

Nutrients-P Loads and In-lake Concentrations

Metrics one and two were calculated from the major tributaries of each basin using method in Dolan and Chapra (2012). The major tributaries are those that taken together contribute more than 80 percent of the TP load to the system of concern. Daily flow measurement by United States Geological Survey (USGS) gauge station with at least between 12 and 24 TP concentration measurements annually (depending on flashiness of the tributary) with an emphasis of the concentration sampling (~two-thirds of samples) on high-flow events in late fall and spring. The contractor did not feel qualified to calculate load estimates from river chemical and flow monitoring stations. The CIW will need to acquire the load estimates from others with more experience in this field. If more recent loads calculated using the methods described in Dolan and Chapra are not available, alternative load estimates may need to be explored. The contractor also did not feel qualified to determine if water quality sampling is sufficient in the Great Lakes, but were able to supply some data.

Metric 1: TP Loads from major tributaries has long-term data, but some data are summarized by basin or subbasin rather than tributary and equivalent data after 2008 may not be available. The availability and comparability of flow and in-stream concentrations of TP were also discussed. The contractor questioned if there a list of "major tributaries" or if the tributaries listed in Dolan and Chapra (2012) were sufficient. Further, they questioned which tributaries were desired for Lake Erie.

Metric 2: DRP Loads from major tributaries has long-term data for limited locations (mostly US portion of Eastern Lake Erie and Lake Michigan), and data after 2008 for Lake Michigan may not be available.

The CIW may need to pursue further avenues to obtain data from Canadian locations for metrics two, three, and four as the contractor did not have the authority to gain access to that data.

Metric 3: Total Phosphorus (TP) concentration in lakes data is available from several sources, but some standardization is needed to account for sampling differences. Long-term data are available for offshore sites, but not for nearshore sites.

Metric 4: DRP concentration in lakes data is available from several sources, but some standardization is needed to account for sampling differences. Long-term data are available for offshore sites, but not for nearshore sites.

PBTs in Biota

The contractor provided contact information for further investigation of each metric, with a description of whether information was current, and if it was primary or auxiliary.

Metric 1 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes whole fish (primarily lake trout, walleye, rainbow smelt but also potentially yellow perch and spottail shiners). PBTs include organochloride pesticides, dioxins and furans, and trace metals (i.e., mercury). A comprehensive monitoring program is maintained by the Environmental Protection Agency (EPA) and Environment Canada (EC), and significant efforts have been made in the past to track various temporal and spatial trends of PBTs in whole fish. There is sufficient information to calculate this indicator. The contractor provided contact information for further investigation of this metric.

Metric 2 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes herring gull eggs. PBTs include organochloride pesticides, dioxins and furans, and trace metals (i.e., mercury). There is a consistent monitoring program maintained by the Ecotoxicology and Wildlife Health Division at Environment Canada, and it should not be difficult to include calculate this metric as it has been done previously for SOLEC reports. The contractor provided contact information for further investigation of this metric.

Metric 3 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes bald eagles. PBTs include organochloride pesticides, dioxins and furans, and trace metals (i.e., mercury).

Harmful and Nuisance Algae

The contractor provided contact information for further investigation of each metric, with a description of whether information was current, and if it was primary or auxiliary.

Metric 1 - Metric measures frequency and magnitude of harmful algae blooms, assigning scores of good, moderate, and severe. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds. Metric focuses on the concentrations of Microcystin-LR or the concentrations of chlorophyll a and communities dominated by cyanobacterial species.

Metric 2 - Metric measures frequency and magnitude of nuisance algae blooms, assigning scores of good, moderate, and severe. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds. Metric focuses on the concentrations of chlorophyll a and levels of common algal odor compounds or occurrence of a "significant number of beach closings".

Metric 3 - Indicator measures frequency and magnitude of harmful and nuisance algae blooms, assigning scores of good, moderate, and severe for 1) harmful algal blooms, 2) nuisance algal blooms, and 3) excessive algal abundance. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds.

Fish Species of Interest

The contractor provided contact information for further investigation of each metric, with a description of whether information was current, and if it was primary or auxiliary.

Metrics one and two measure the status and trends in population abundance and recruitment respectively of cold water species, including lake trout and lake whitefish**.** These metrics emphasize model generated estimates over fisheries surveys or commercial catch statistics. These are offshore species that are ecologically and economically important so significant effort has been made to characterize their population dynamics. It should be fairly straight-forward for experts from the Lake Technical Committees to assign scores for these species based on the wealth of data available and previously developed population models.

Metrics three and four measure the status and trends in population abundance and recruitment respectively of cool water species a walleye. These metrics emphasize model generated estimates over fisheries surveys or commercial catch statistics. Walleye are fairly well studied in locations where they are abundant, such as Lake Erie and embayment in Lakes Michigan and Huron. In some of these locations, population models have often been developed, which can be used to assess abundance and recruitment. In locations without population models, monitoring surveys can likely be used to assess temporal trends in the catch per unit effort (CPUE) and provide an index of recruitment.

Metrics five and six measure the status and trends in population abundance and recruitment respectively for lake sturgeon. These metrics emphasize model generated estimates over fisheries surveys or commercial catch statistics. Lake sturgeon populations are monitored throughout the basin by assessing adult numbers in spawning tributaries. The amount of effort within and across years is highly variable making it challenging to integrate multiple data sources across years to develop trend analyses. No population models have been developed for lake sturgeon, and most work focuses on differentiating specific populations/stocks. Assessing trends in recruitment will likely be limited to a few locations that have long-term monitoring programs to assess larval and age-0 abundances in tributaries. These are likely associated with the largest populations. For smaller populations, monitoring of recruitment is not done or only done for a few years.

Metrics seven and eight measure the status and trends in population abundance and recruitment respectively for warm water species, including northern pike, and smallmouth bass/largemouth bass. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics. Calculation of population abundance will likely need to be based on CPUE effort trends in fish community surveys, since no population models exist for these species. The ability to calculate this metric will vary across and within lakes depending on the quality of available datasets. Calculations of recruitment will likely need to be based on CPUE effort trends in fish community surveys; however, assessment of recruitment for these fish species will likely be difficult as most of the available data focuses on the adult fish community. Several coastal trawl surveys across the basin may provide some ability to assess recruitment of smallmouth bass, while assessment of northern pike recruitment is likely limited to the St. Lawrence.

Appendix B: Complete List of Metric Data Provided by Contractor

Seasonal and long-term fluctuations in Great Lakes water levels

Metric 1: Long-term water level variability

Data description		Data Availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 Department of Fisheries and Oceans (DFO) monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes.
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gages began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but USACE has concerns about the quality of pre-1918 water level data. Drew Gronewold, a USGS expert on water levels believes pre-1918 water levels are comparable and should be used to maximize the period of record.

	Calibrated within and across collection methods?	Yes. The current network of gages on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gage data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1860s.
	Has established endpoints, goals, criteria?	Goals are clearly stated and established but no specifics are provided as to how to translate observed water level variability into an ecological condition assessment. SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels. (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA National Ocean Service (NOAA-NOS), and the DFO - Canadian Hydrographic Survey (CHS). Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Metric 2: Timing of Seasonal Min Water Level

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 DFO monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gauges began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None.
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but see previous comments about USACE concerned about including pre-1918 water level data.

	Calibrated within and across collection methods?	Yes. The current network of gauges on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gauge data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1860s.
	Has established endpoints, goals, criteria?	Goals are clearly stated and established but no specifics are provided as to how to translate observed change in the timing of water level minima into an ecological condition assessment. SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels" (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA-NOS and the DFO-CHS. Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Metric 3: Timing of Seasonal Max Water Level

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 DFO monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gauges began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but see previous comments about USACE concerned about including pre-1918 water level data.

	Calibrated within and across collection methods?	Yes. The current network of gauges on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gauge data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1840s.
	Has established endpoints, goals, criteria?	Goals are clearly stated and established but no specifics are provided as to how to translate observed change in the timing of water level maxima into an ecological condition assessment. SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels" (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA-NOS and the DFO-CHS. Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Metric 4: Magnitude of seasonal rise

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 DFO monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gages began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but see previous comments about USACE concerned about including pre-1918 water level data.

	Calibrated within and across collection methods?	Yes. The current network of gages on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gage data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1840s.
	Has established endpoints, goals, criteria?	Goals are clearly stated and established; No specifics are provided on how to translate observed within- and between-lake water level variability and seasonal changes in water level timing into an ecological condition assessment. SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels" (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA-NOS and the DFO-CHS. Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Metric 5: Magnitude of seasonal decline

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 DFO monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gages began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but see previous comments about USACE concerned about including pre-1918 water level data.

	Calibrated within and across collection methods?	Yes. The current network of gages on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gage data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1860s.
	Has established endpoints, goals, criteria?	Goals are clearly stated and established; No specifics are provided on how to translate observed within- and between-lake water level variability and seasonal changes in water level timing into an ecological condition assessment. SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels" (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA-NOS and the DFO-CHS. Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Metric 6: Lake to Lake water level difference

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. But water levels commonly reported by lake.
	Individual lakes	Yes. (Note: Lake Michigan and Lake Huron are treated as a single, hydraulically connected lake referred to as Lake Michigan-Huron)
	Subunit of lakes	Water levels are commonly summarized by lake; the subbasin spatial extent is not appropriate for calculation of this indicator.
	Collection locations	Water levels are commonly summarized by lake; There are a total of 53 NOAA and 33 DFO monitoring stations in the Great Lakes and connecting channels and lakes; Lakewide values are from the "Master Station" in each lake.
Regularly monitored	Is metric regularly monitored?	Yes
	What is the monitoring cycle?	As small as every six minutes at certain stations; Summaries by month or year easily acquired.
Length of monitoring record	What is period of record?	Systematic records from all lakes began in 1860, but rigorous monitoring with multiple gauges began in 1918; There are two possible data records to use: 1) 1860-present with pre-1918 data adjusted for glacial isostatic rebound (Drew Gronewold argues for this) or 2) 1918-present (USACE argues for this).
	Any major gaps in record?	None
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes, but see previous comments about USACE concerned about including pre-1918 water level data.
	Calibrated within and across collection methods?	Yes. The current network of gauges on each lake has been in operation since 1918 and is fully calibrated. There is some debate as to whether pre-1918 lake averages can be combined with current gauge data. Several gauges in the current network of multiple gauges have been in operation only since 1918, while others have gauge records (some less reliable) extending back to the 1860s.

	Has established endpoints, goals, criteria?	Goals are clearly stated and established; Indicator report suggests differences between the water levels of each of the lakes may follow a relatively consistent and predictable pattern; anomalies in these differences may suggest an imbalance in the regional water budget, physical changes in the channels that connect the lakes, or the apparent and physical impacts of glacial isostatic adjustment on recorded water levels (International Upper Great Lakes Study, 2009). SOLEC 2011 report: "The recorded water level history is insufficient to capture a complete understanding of lake level variability. Rise and fall patterns showing a degree of periodicity in millennial timescale can be seen in reconstructed water level histories extended into the past, prior to the period of recorded water levels" (USGS, 2005; Wilcox et al., 2007; Sellinger et al., 2007).
Owner and cost	Metric has "owner(s)" (Y/N)	Measuring lake water levels is a central regional mission of both the NOAA-NOS and the DFO-CHS. Synthesizing and communicating lakewide-average water level data is coordinated through a regional partnership led by the USACE Detroit District, and EC. Data are available online through the water level dashboard at http://www.glerl.noaa.gov/data/dashboard/data/. Drew Gronewold is the primarily contact. The lake water level monitoring program is well established, has stable funding, and is expected to continue.
	Estimated cost	Not able to assess cost of water level monitoring or data dissemination. There are minimal costs associated with data processing to calculate this metric.

Water temperature

Metric 1: Annual summer (July-September) surface average temperature for each lake

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes if calculated with the Great Lakes Surface Environmental Analysis (GLSEA) Sea Surface Temperature (SST) model data; Severe spatial limitations if calculated with direct measurements from buoys with long-term data (only three such buoys in SU, two in MI, two in HU, and one in ER and all of these buoys are located far offshore; Lake Ontario buoys have a much shorter monitoring period of record).
Rigorously monitored to report statistically meaningful results	Entire basin	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and with a shorter period of record for Lake Ontario.
	Individual lakes	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and shorter period of record for Lake Ontario
	Subunit of lakes	Yes if calculated with the GLSEA SST data; No, if based on buoy data (limited replication within subbasins and not all subbasins have long-term buoy data).
	Collection locations	GLSEA SST is derived from satellite data at a 2.6 km (1994-2003) or at 1.3 km to 0.8 km (2003-2014) grid resolution. These resolutions allows for summary of GLSEA SST data at multiple spatial extents (e.g., subbasin, lake, GLB). Buoy measured temperatures are point locations and buoys with long term data (i.e., beginning as early as 1979) are all offshore with one to three buoys in a lake.
Regularly monitored	Is metric regularly monitored?	Yes for both GLSEA SST and buoys.
	What is the monitoring cycle?	Surface water temperature is modelled in daily increments in GLSEA SST and buoy temperature measurements are reported daily. Buoys are deployed in the spring after ice off and are removed in the fall before significant ice formation.
Length of monitoring record	What is period of record?	GLSEA SST modelled surface water temperature is 1994-2014 (Note: Although this is a comparatively shorter period of record than some buoys, analyses on these data have been sufficient to shown trends in temperature in the Great Lakes). There are eight buoys in the GL that have period of record from approximately 1979 to present (three such buoys in SU, two in MI, two in HU, and one in ER). The period of record for Lake Ontario begins in 2002. Over the past decade many more buoys have been added to the Great Lakes but their deployment year and the continuity of temperature data restricts use for calculating this indicator.

	Any major gaps in record?	None for GLSEA SST model temperatures and none for buoys with long-term data.
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes.
	Calibrated within and across collection methods?	Collection methods are standardized across the GLB because data collection and GLSEA SST models are applied basinwide.
	Has established endpoints, goals, criteria?	Nothing specific. Indicator assessment is written in generalized statements: "Higher water temperatures ... may be related to more and earlier algae blooms which damage water quality and habitat; ... and higher temperatures may also be related to the spread of some invasive species." However, trends in the indicator can be measured by increases in temperature surface water temperature.
Owner and cost	Metric has "owner(s)" (Y/N)	Surface water temperatures are available as direct measures of surface temperature from buoys and as modelled surface water temperature based on satellite data. These monitoring efforts are expected to continue for the foreseeable future. NOAA's National Data Buoy Center is the lead organization on long-term buoy data. NOAA CoastWatch produces the GLSEA SST data, which is a mean daily surface temperature product covering all of the Great Lakes and is derived from Advanced very high resolution radiometer (AVHRR) satellite imagery (Schwab et al. 1999). The direct temperature measurements from buoys can be downloaded from the web at http://www.ndbc.noaa.gov/. Summary statistics on GLSEA are available for download at http://coastwatch.glerl.noaa.gov/statistic/statistic.html. High-resolution SST data were provided to the GLAHF by David Schwab and integrated into the GLAHF framework by Lacey Mason.
	Estimated cost	Not able to assess cost of water temperature monitoring. There are minimal costs associated with data processing to calculate this metric.

Metric 2: Lake water thermal stratification date

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes if calculated with the GLSEA SST model data; Analyses limited to offshore locations and may not have sufficient period of record for Lake Ontario if calculated with direct measurements from buoys with long-term data (only three such buoys in SU, two in MI, two in HU, and one in ER; Lake Ontario buoys have a much shorter monitoring period of record).
Rigorously monitored to report statistically meaningful results	Entire basin	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and with a shorter period of record for Lake Ontario.
	Individual lakes	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and shorter period of record for Lake Ontario
	Subunit of lakes	Yes if calculated with the GLSEA SST data; No, if based on buoy data (limited replication within subbasins and not all subbasins have long-term buoy data).
	Collection locations	GLSEA SST is derived from satellite data at a 2.6 km (1994-2003) or at 1.3 km to 0.8 km (2003-2014) grid resolution. These resolutions allows for summary of GLSEA SST data at multiple spatial extents (e.g., subbasin, lake, GLB). Buoy measured temperatures are point locations and buoys with long term data (i.e., beginning as early as 1979) are all offshore with one to three buoys in a lake.
Regularly monitored	Is metric regularly monitored?	Yes for both GLSEA SST and buoys.
	What is the monitoring cycle?	Surface water temperature is modelled in daily increments in GLSEA SST and buoy temperature measurements are reported daily. Buoys are deployed in the spring after ice off and are removed in the fall before significant ice formation.

Length of monitoring record	What is period of record?	GLSEA SST modelled surface water temperature is 1994-2014 (Note: Although this is a comparatively shorter period of record than some buoys, analyses on these data have been sufficient to shown trends in temperature in the Great Lakes). There are eight buoys in the GL that have period of record from approximately 1979 to present (three such buoys in SU, two in MI, two in HU, and one in ER). The period of record for Lake Ontario begins in 2002. Over the past decade many more buoys have been added to the Great Lakes but their deployment year and the continuity of temperature data restricts use for calculating this indicator.
	Any major gaps in record?	None for GLSEA SST model temperatures and none for buoys with long-term data.
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes.
	Calibrated within and across collection methods?	Collection methods are standardized across the GLB because data collection and GLSEA SST models are applied basinwide.
	Has established endpoints, goals, criteria?	Nothing specific. Indicator assessment is written in generalized statements: "Higher water temperatures and less ice cover may be related to more and earlier algae blooms which damage water quality and habitat; less ice cover exposes the shoreline to waves generated by winter storms that accelerates erosion; and higher temperatures may also be related to the spread of some invasive species." However, assessment of this metric could be measured as any change in timing of Spring stratification.

Owner and cost	Metric has "owner(s)" (Y/N)	Surface water temperatures are available as direct measures of surface temperature from buoys and as modelled surface water temperature based on satellite data. These monitoring efforts are expected to continue for the foreseeable future. NOAA's National Data Buoy Center is the lead organization on long-term buoy data. NOAA CoastWatch produces the GLSEA SST data, which is a mean daily surface temperature product covering all of the Great Lakes and is derived from AVHRR satellite imagery (Schwab et al. 1999). The direct temperature measurements from buoys can be downloaded from the web at http://www.ndbc.noaa.gov/. Summary statistics on GLSEA are available for download at http://coastwatch.glerl.noaa.gov/statistic/statistic.html. High-resolution SST data were provided to GLAHF by David Schwab and integrated into the GLAHF framework by Lacey Mason.
	Estimated cost	Not able to assess cost of stratification timing monitoring. There are minimal costs associated with data processing to calculate this metric.

Metric 3: Fall lake water turnover date

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes if calculated with the GLSEA SST model data; Analyses limited to offshore locations and may not have sufficient period of record for Lake Ontario if calculated with direct measurements from buoys with long-term data (only three such buoys in SU, two in MI, two in HU, and one in ER; Lake Ontario buoys have a much shorter monitoring period of record).
Rigorously monitored to report statistically meaningful results	Entire basin	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and with a shorter period of record for Lake Ontario.
	Individual lakes	Yes if calculated with the GLSEA SST data; If based on buoy data, limited to offshore and shorter period of record for Lake Ontario
	Subunit of lakes	Yes if calculated with the GLSEA SST data; No, if based on buoy data (limited replication within subbasins and not all subbasins have long-term buoy data).
	Collection locations	GLSEA SST is derived from satellite data at a 2.6 km (1994-2003) or at 1.3 km to 0.8 km (2003-2014) grid resolution. These resolutions allows for summary of GLSEA SST data at multiple spatial extents (e.g., subbasin, lake, GLB). Buoy measured temperatures are point locations and buoys with long term data (i.e., beginning as early as 1979) are all offshore with one to three buoys in a lake.
Regularly monitored	Is metric regularly monitored?	Yes for both GLSEA SST and buoys.
	What is the monitoring cycle?	Surface water temperature is modelled in daily increments in GLSEA SST and buoy temperature measurements are reported daily. Buoys are deployed in the spring after ice off and are removed in the fall before significant ice formation.

Length of monitoring record	What is period of record?	GLSEA SST modelled surface water temperature is 1994-2014 (Note: Although this is a comparatively shorter period of record than some buoys, analyses on these data have been sufficient to shown trends in temperature in the Great Lakes). There are eight buoys in the GL that have period of record from approximately 1979 to present (three such buoys in SU, two in MI, two in HU, and one in ER). The period of record for Lake Ontario begins in 2002. Over the past decade many more buoys have been added to the Great Lakes but their deployment year and the continuity of temperature data restricts use for calculating this indicator.
	Any major gaps in record?	None for GLSEA SST model temperatures and none for buoys with long-term data.
Calibration and endpoints	Calibrated to account for natural variation across space and time?	Yes.
	Calibrated within and across collection methods?	Collection methods are standardized across the GLB because data collection and GLSEA SST models are applied basinwide.
	Has established endpoints, goals, criteria?	Nothing specific. Indicator assessment is written in generalized statements: "Higher water temperatures and less ice cover may be related to more and earlier algae blooms which damage water quality and habitat; less ice cover exposes the shoreline to waves generated by winter storms that accelerates erosion; and higher temperatures may also be related to the spread of some invasive species." However, assessment of this metric could be measured as any change in timing of spring stratification.

Owner and cost	Metric has "owner(s)" (Y/N)	Surface water temperatures are available as direct measures of surface temperature from buoys and as modelled surface water temperature based on satellite data. These monitoring efforts are expected to continue for the foreseeable future. NOAA's National Data Buoy Center is the lead organization on long-term buoy data. NOAA CoastWatch produces the GLSEA SST data, which is a mean daily surface temperature product covering all of the Great Lakes and is derived from AVHRR satellite imagery (Schwab et al. 1999). The direct temperature measurements from buoys can be downloaded from the web at http://www.ndbc.noaa.gov/. Summary statistics on GLSEA are available for download at http://coastwatch.glerl.noaa.gov/statistic/statistic.html. High-resolution SST data were provided to GLAHF by David Schwab and integrated into the GLAHF framework by Lacey Mason.
	Estimated cost	Not able to assess cost of fall mixing timing monitoring. There are minimal costs associated with data processing to calculate this metric.

Metric 4: Maximum and average ice concentrations

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes.
	Individual lakes	Yes.
	Subunit of lakes	Yes.
	Collection locations	Ice cover is derived from satellite data. Ice cover grid resolutions depends on the year of record but is either approximately a 2.5 or 1.3 km grid (grid size varies somewhat with latitude and changed from 2.5 km grid to 1.3 km grid beginning in 2007).
Regularly monitored	Is metric regularly monitored?	Yes.
	What is the monitoring cycle?	Ice cover is measured throughout each ice season (defined as 1 December to the following 31 May). The number of ice charts per winter varies with year: 1973-1988 approx. 20, 1989-1996 approx. 80, 1993-2002 approx. 40, 2003-2010 approx. 50; 2011 = 151 ice charts; This the average number of days between ice charts has varied over the period of record.
Length of monitoring record	What is period of record?	1973-present; Within an ice season, a temporal linear interpolating of ice concentration between consecutive observed ice chart grids, cell by cell, for a given winter season was used to create the daily grids.
	Any major gaps in record?	None.
Calibration and endpoints	Calibrated to account for natural variation across space and time?	For the most part, yes. There is a slightly greater lake-averaged ice cover for the larger grids (i.e., before 2007), but the maximum differences are two percent, and differences are less than two percent in most cases. This is considered sufficiently accurate for climate studies (Wang et al. 2012).
	Calibrated within and across collection methods?	Collection methods are standardized across the GLB because data collection and models are applied basinwide.

	Has established endpoints, goals, criteria?	Nothing specific. Indicator assessment is written in generalized statements: "...less ice cover may be related to more and earlier algae blooms which damage water quality and habitat; less ice cover exposes the shoreline to waves generated by winter storms that accelerates erosion." However, assessment of this metric could be measured as change in the maximum and/or average ice cover.
Owner and cost	Metric has "owner(s)" (Y/N)	Ice cover data are available from NOAA and will continue to be monitored for the foreseeable future. GLAHF has daily ice cover values for each season for 1973-2013. Ice cover in GLAHF were downloaded from Assel 2003, more commonly known as the NOAA Great Lakes Ice Atlas (GLIA), a 33-winter set of composite ice charts covering the entire Great Lakes from 1973 to 2005. Data for recent years are also incorporated into GLAHF and available from NOAA-GLERL at http://www.natice.noaa.gov/products/great_lakes.html. The NOAA Great Lakes Ice Atlas is at http://www.glerl.noaa.gov/data/ice/atlas/ (1973-2002, with links to 2003-2005 and 2006-2011 data as well).
	Estimated cost	Not able to assess cost of ice cover monitoring. There are minimal costs associated with data processing to calculate this metric.

Nutrients-P loads and in-lake concentrations

Metric 1: TP Loads from major tributaries

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	TP loads data are generally available and summarized for major tributaries or lake subbasins across the GLB; When load calculations are not available, two sources of primary data are required to calculate annual load estimates: 1) Streamflow and 2) In-stream TP concentrations (especially during high flow events). Chapra and Dolan 2012 provide 1994-2008 annual TP loads for Canadian and United States tributaries to Lakes Superior, Huron, Michigan, and Ontario. Loads for Lake Erie are summarized at the subbasin spatial extent, but the original tributary-based load data are likely available.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes, but rigor of monitoring program varies with lake (Lake Erie is the most heavily monitored). Canadian-led monitoring programs do not include Lake Michigan.
	Individual lakes	Yes, but rigor of monitoring program varies with lake (Lake Erie is the most heavily monitored). Canadian-led monitoring programs do not include Lake Michigan.
	Subunit of lakes	Yes for data from 1994 to 2008. Loading data is generally available by watershed and/or subbasin. Older (i.e., prior to 1994) TP load data are available as summaries at the subbasin or basin spatial extent. Indicator summary states load data are to be at the tributary spatial extent.
	Collection locations	Indicator metric is based on annual loads for major tributaries in GLB; For load calculations, tributaries are essentially represented as pour points in the GLB. Annual load estimates are calculated from streamflow and in-stream concentration monitoring programs. Ballard LaBeau et al. 2013 examines the tributary monitoring network currently in place for sampling the amount of phosphorus entering the US Great Lakes, focusing on the challenges faced by the agencies and organizations responsible for maintaining the network. They summarize differences between sampling programs in Table 4.
Regularly monitored	Is metric regularly monitored?	For portions of the record, yes. Annual TP tributary load estimates are available for 1994-2008; Despite multiple attempts, we were able to identify who is responsible, if anyone, for post-2008 calculations following methods described in Dolan and Chapra 2012. Primary data on which loads could be calculated are available and regularly monitored. US daily average tributary flows for gauged tributaries are available from the National Water Information System (NWIS) database maintained by the Water Resources Division

		of the USGS and Canadian daily average tributary flows for gauged tributaries are available from the Hydrometric Data (HYDAT) database maintained by EC, Water Survey Canada. US tributary TP concentrations available in STORET, the US EPA database for water quality data and Canadian tributary TP concentrations are available from the Provincial Water Quality Monitoring Network (PWQMN) database at the Ontario Ministry of the Environment (OMOE).
	What is the monitoring cycle?	Load estimates are annual loads. These load estimates are based on in-stream TP concentrations which are recommended to be monitored at least 12-24 times per year (especially during high-flow events) depending on flashiness of the tributary.
Length of monitoring record	What is the period of record?	Great Lakes TP loadings have been estimated since 1967, although the spatial extent at which these loads are summarized varies with year. Load estimates calculated using comparable methods are available for approximately 1981-2008, with 1994-2008 loads from Dolan and Chapra (2012). USGS tributary flow monitoring began in the early 1970s. Heidelberg University's program began in 1969
	Any major gaps in record?	Yes. Post-2008 load estimates may need to be calculated (if possible). Ballard LaBeau et al. describe a widespread cessation of US-led stream flow and instream phosphorus monitoring in the early 1990s and notable declines in monitoring programs on Lake Erie and Lake Michigan (with the exception of those tributaries monitored by Heidelberg University).
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes, if the same methods can be used to calculate loads across the GLB and monitoring programs are comparable.
	Calibrated within and across collection methods	Yes and no. TP loads Dolan calculated do use consistent load calculation methods. However, Grannemann states "there are some new techniques to estimate loads that may eclipse the Beale estimator that Dolan used. However, the Dolan work is the most consistent information if it can be updated from 2008 to present. The other factor that has changed recently is the use of event-based sampling that does a better job of incorporating high flow events into the calculations. Because data has been collected differently over the years, the question of uncertainty of the estimates is an issue, as is the accuracy of trend data for loading estimates." Another issue is whether differences between, and temporal change in, stream monitoring programs affect load calculations (see Ballard LaBeau et al. 2013 for a detailed review of US monitoring programs). According to Ballard LaBeau et al. (2013), "there are minimal organization connections between state

		monitoring programs. Most programs collect data required to fulfill their particular mission, which can differ significantly from state to state." Some states focus on sampling during storm events, others do not, some states monitor the same sites year after year, others rotate, and some use a flow-stratified sampling design, other do not.
	Has established endpoints, goals, criteria	Not specified in the indicator summary, but tributary loads could be summed by subbasin or basin and compared to lake-specific phosphorus load targets. Trends over time (e.g., slope of trend line) could also be calculated for each tributary and assessments of trends summarized by tributary, subbasin, or basin.
Owner and cost	Metric has "owner(s)" (Y/N)	TP loading data has primarily been organized by Dolan; however, he died unexpectedly in 2013 and we have been unable to identify if anyone has taken over responsibility for these load calculations. The Lake Erie tributary monitoring program is maintained by Heidelberg University and is directed by Kenneth A. Krieger and David Baker. US daily average tributary flows for gauged tributaries are available from the NWIS database maintained by the Water Resources Division of the USGS and Canadian daily average tributary flows for gauged tributaries are available from the HYDAT database maintained by EC, Water Survey Canada. US tributary TP concentrations are available in STORET (usually after a several year delay), the US EPA database for water quality data and Canadian tributary TP concentrations are available from the PWQMN database at the OMOE.
	Estimated cost	We are unable to estimate total costs: Estimates would need to include cost of streamflow monitoring stations in the GLB, TP monitoring programs in the GLB, costs associated with compiling flow and TP concentration data, and costs associated with the calculation of TP loads. The Heidelberg program estimates each monitoring station costs "in the neighborhood of $40,000" per year to operate (three samples per site daily, ten sites) and Ballard LaBeau et al. (2013) estimate the cost of tributary monitoring programs varies from $15,000 to $40,000 per site per year depending on the temporal sampling design and parameters tested.

Metric 2: DRP Loads from major tributaries

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Long-term load data may be limited to US portion of Lake Erie and Lake Michigan.
Rigorously monitored to report statistically meaningful results	Entire basin	No. Long-term load data likely limited to US portion of Eastern Lake Erie and Lake Michigan. Mark Rowe has compiled DRP loads as calculated by David Dolan for tributaries to Lake Michigan. It is possible that Dolan calculated DRP loads for tributaries throughout the GLB but due to his untimely death, these data are likely unavailable.
	Individual lakes	No. Long-term load data likely limited to US portion of Eastern Lake Erie and Lake Michigan. Mark Rowe has compiled DRP loads as calculated by David Dolan for tributaries to Lake Michigan. It is possible that Dolan calculated DRP loads for tributaries throughout the GLB but due to his untimely death, these data are likely unavailable.
	Subunit of lakes	No. Long-term load data likely limited to US portion of Eastern Lake Erie and Lake Michigan. Mark Rowe has compiled DRP loads as calculated by David Dolan for tributaries to Lake Michigan. It is possible that Dolan calculated DRP loads for tributaries throughout the GLB but due to his untimely death, these data are likely unavailable.
	Collection locations	Indicator metric is based on annual loads for major tributaries in GLB; For load calculations, tributaries are essentially represented as pour points in the GLB. Trends for individual tributaries could be examined in both Eastern Lake Erie and Lake Michigan. The Heidelberg project currently includes 15 tributaries although some of these are recent additions to the monitoring program. The dataset from Mark Rowe includes 12 to 15 tributaries (not all have data each year). Annual load estimates are calculated from streamflow and in-stream concentration monitoring programs. Ballard LaBeau et al. 2013 examines the tributary monitoring network currently in place for sampling the amount of phosphorus entering the US Great Lakes, focusing on the challenges faced by the agencies and organizations responsible for maintaining the network. They summarize differences between sampling programs in Table 4.

Regularly monitored	Is metric regularly monitored?	Yes in Eastern Lake Erie and somewhat in Lake Michigan (limited to annual loads calculated by Dolan from 1994-2008).
	What is the monitoring cycle?	Load estimates are annual loads. These load estimates are based on in-stream DRP concentrations which are recommended to be monitored at least 12-24 times per year (especially during high-flow events) depending on flashiness of the tributary.
Length of monitoring record	What is the period of record?	1975 to present for Heidelberg project in Eastern Lake Erie; 1994-2008 for Lake Michigan
	Any major gaps in record?	None for Eastern Lake Erie; No post 2008 DRP loads for Lake Michigan
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes, if the same methods are used to calculate loads.
	Calibrated within and across collection methods	Yes and no. DRP loads Dolan calculated for Lake Michigan do use consistent load calculation methods, as do load calculations produced by Heidelberg University. However, Grannemann states "there are some new techniques to estimate loads that may eclipse the Beale estimator that Dolan used. However, the Dolan work is the most consistent information if it can be updated from 2008 to present. The other factor that has changed recently is the use of event-based sampling that does a better job of incorporating high flow events into the calculations. Because data has been collected differently over the years, the question of uncertainty of the estimates is an issue, as is the accuracy of trend data for loading estimates." For Lake Michigan load estimates, another issue is whether differences between, and temporal change in, stream monitoring programs affect load calculations (see Ballard LaBeau et al. 2013 for a detailed review of US monitoring programs). According to Ballard LaBeau et al. (2013), "there are minimal organization connections between state monitoring programs. Most programs collect data required to fulfill their particular mission, which can differ significantly from state to state." Some states focus on sampling during storm events, others do not, some states monitor the same sites year after year, others rotate, and some use a flow-stratified sampling design, other do not.
	Has established endpoints, goals, criteria	Not specified in the indicator summary, but tributary loads could be summed by subbasin or basin and compared to lake-specific phosphorus load targets. Trends over time (e.g., slope of trend line) could also be calculated for each tributary and assessments of trends summarized by tributary, subbasin, or basin.

Owner and cost	Metric has "owner(s)" (Y/N)	The Lake Erie tributary monitoring program is maintained by Heidelberg University and is directed by Kenneth A. Krieger and David Baker. All of the river data resulting from this project can be downloaded at their data download web site http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data/data. Mark Rowe provided summarized Lake Michigan DRP loads as calculated by David Dolan. US daily average tributary flows for gauged tributaries are available from the NWIS database maintained by the Water Resources Division of the USGS and Canadian daily average tributary flows for gauged tributaries are available from the HYDAT database maintained by EC, Water Survey Canada. US tributary TP concentrations are available in STORET (usually after a several year delay), the US EPA database for water quality data and Canadian tributary TP concentrations are available from the PWQMN database at the OMOE.
	Estimated cost	We are unable to estimate total costs: Estimates would need to include cost of streamflow monitoring stations in the GLB, DRP monitoring programs in the GLB, costs associated with compiling flow and TP concentration data, and costs associated with the calculation of DRP loads. The Heidelberg program estimates each monitoring station costs "in the neighborhood of $40,000" per year to operate (three samples per site daily, ten sites) and Ballard LaBeau et al. (2013) estimate the cost of tributary monitoring programs varies from $15,000 to $40,000 per site per year depending on the temporal sampling design and parameters tested.

Metric 3: Total Phosphorus (TP) concentration in lakes

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Within lake nutrient levels are available for offshore habitats through EPA Great Lakes National Program Office (GLNPO) and EC for all five lakes. However, there is comparatively limited nearshore sampling through OMOE and EPA (this monitoring is not as frequent and does not have as long a record as offshore concentration monitoring). All in-lake monitoring programs are simply snap shots in time and sampling may not be sufficient to truly understand in-lake phosphorus dynamics. This concern may decrease as the Coordinated Science and Monitoring Initiative focuses on a better characterization of nearshore/offshore gradients.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes for offshore TP concentrations and somewhat for nearshore TP concentrations (nearshore monitoring is not as frequent and does not have as long a record as offshore concentration monitoring).
	Individual lakes	Yes, however Canadian-led monitoring programs do not include Lake Michigan. Nearshore monitoring stations are monitored by different state and national programs, therefore these stations are specific to each nation's own shoreline. Additional sampling programs focus on (or will focus on) TP concentrations in Lake Erie. Ohio EPA monitoring is limited to the Maumee River estuary, and US nearshore of the Western Basin, Sandusky Basin, and Central basin in Lake Erie. In February 2015, the Ohio Senate passed a bill that will establish a phosphorus monitoring program at many of Lake Erie's water intake facilities, but details of this program are currently in development.
	Subunit of lakes	Yes. In-lake concentration monitoring sites do have multiple sites within a lake subbasin and could be summarized by lake subbasin. Canadian-led monitoring programs do not include Lake Michigan. Additional sampling programs focus on (or will focus on) TP concentrations in Lake Erie. Ohio EPA monitoring is limited to the Maumee River estuary, and US nearshore of the Western Basin, Sandusky Basin, and Central basin in Lake Erie. In February 2015, the Ohio Senate passed a bill that will establish a phosphorus monitoring program at many of Lake Erie's water intake facilities, but details of this program are currently in development.

	Collection locations	Yes. GLNPO samples about 75 offshore sites once in the spring and summer each year and EC samples about 275 sites with each lake monitored every 2nd year. The EPA National Coastal Condition Assessment (NCCA) program sampled 248 sites in 2010. The OMOE visits 10-18 stations each year (lakes on a sampling rotation and program also targets connecting channels and Lake St. Clair). Ohio EPA sampled about 12-18 nearshore sites in Lake Erie from 2011-2013. The indicator description suggests a need to revisit the placement of stations and the depth resolution of sampling to better capture nearshore-offshore gradients on the system and improve the accuracy of basinwide average concentrations of both TP and DRP.
Regularly monitored	Is metric regularly monitored?	Yes. TP In-lake concentrations in offshore habitats are regularly monitored during annual spring and summer monitoring cruises by GLNPO and EC. Nearshore habitats are sampled with differing frequency. The OMOE Great Lakes Index stations are sampled within a year on a rotational basis (i.e., Lakes Ontario and Erie are sampled every three years while Lakes Superior and Huron are sampled every six years). The NCCA nearshore sites were sampled in 2010 and may be re-sampled every five years depending on continued funding. In 2011-2013, Ohio EPA nearshore sampling began after April 1 and continued through September 30. Samples from the Maumee River estuary, Western Basin and Sandusky Basin were collected on a bi-weekly basis while samples from the Central Basin were collected on a monthly basis.
	What is the monitoring cycle?	GLNPO: One sample per station each spring (before stratification) and summer (after stratification); EC: One sample per station each spring (before stratification) and summer (after stratification); OMOE: Ontario and Erie stations sampled every three years, Superior and Huron every six years; NCAA EPA: Possibly every five years; Ohio EPA: Biweekly or monthly in early spring to end of summer.
Length of monitoring record	What is the period of record?	Varies with monitoring program. GLNPO offshore period of record is as long as 1983-present (although start date varies with lake and some seasonal cruises were skipped in early years); EC is 1974 to present (even older data are available, but these are not comprehensive and might not be comparable to post-1974 measures); EPA NCCA is 2010 only; OMOE nearshore is 2003-present; Ohio EPA nearshore monitoring is for 2011-2013 (with hopes of becoming an ongoing monitoring program).
	Any major gaps in record?	Minor gaps and regularly occurring gaps due to rotating sampling. There is no

		GLNPO concentration monitoring from 1994-1995. Both Canadian nearshore and offshore monitoring programs sample lakes on a rotational basis rather than annually.
Calibration and endpoints	Calibrated to account for natural variation across space and time	Within a program, concentration monitoring is highly standardized across years, seasons, sites, and lakes. Sample stations are consistently revisited.
	Calibrated within and across collection methods	Sampling and sample processing is calibrated within a sampling program. These programs use largely comparable analytic techniques (but see note below concerning digestion time), but there are differences in how samples are collected. For example GLNPO and OMOE sample at certain depths in the depth profile and include a water column composite sample, while EC focuses on sampling surface water. These sampling differences can be accounted for in data summary approaches. For example, SOLEC commonly reports concentrations from surface water (top three metres). However, a comparison of Canadian and United States TP data in Lakes Huron and Ontario indicate consistently higher TP values are obtained by EC relative to GLNPO (even at shared stations; differences of about 1.9 and 1.6 µg/L respectively for Lakes Ontario and Huron respectively; SOLEC 2011). These differences are not due to laboratory instruments or sampling timing or location. The difference is likely due to differing sample digestion durations (slightly longer for EC and thus could result in more complete breakdown of nutrients attached to particles resulting in slightly higher concentrations). EPA NCAA data are not currently available, limiting a complete assessment of collection methods. Ohio EPA uses a SeaBird® profiler (also used by GLNPO) or YSI® Pro Series meter and samples at various depths depending on stratification status. These sample depths are comparable to those collected by other programs.
	Has established endpoints, goals, criteria	Not specified in the indicator summary, but in-lake TP concentrations could be averaged by subbasin or basin and compared to lake-specific concentration targets such as those in the GLWQA (i.e., 5 µg/L for Superior and Huron, 7 µg/L for Michigan, 10 µg/L for Ontario, 15 µg/L for western Lake Erie, and 10 µg/L for Central and Eastern Lake Erie).
Owner and cost	Metric has "owner(s)" (Y/N)	Within-lake data TP concentration data are maintained by various organizations: EPA GLNPO contact is Glenn Warren and data are available for download directly from the EPA CDX portal; EC contact is Alice Dove; EPA NCCA contact is Beth

		Hinchey Malloy; OMOE contact is Mary Thorburn; Ohio EPA contact is currently unknown, but a project document indicates data will be sent to the US EPA Water Quality Exchange. GLAHF is in possession of some of the in-lake concentration TP sample data and has experience processing such data.
	Estimated cost	No cost estimates were available for GLNPO, EC, and NCCA programs, but full contact information for Glenn Warren, Alice Dove, Beth Hinchey Malloy, and Mary Thorburn are provided. Ohio EPA estimates the cost of each TP concentration sample at $23 (Ohio EPA 2014, page 10). However, it is not clear exactly what this estimate includes (e.g., just concentration determination or does it include the full cost of a sample including boat maintenance, use, and personnel, sample collection and storage, concentration testing, data entry and dissemination data, etc.).

Metric 4: DRP concentration in lakes

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Within lake DRP concentrations are available for offshore habitats through EPA GLNPO and EC for all five lakes. However, there is comparatively limited nearshore sampling through OMOE and EPA (this monitoring is not as frequent and does not have as long a record as offshore concentration monitoring). All in-lake monitoring programs are simply snap shots in time and sampling may not be sufficient to truly understand in-lake phosphorus dynamics. This concern may decrease as the Coordinated Science and Monitoring Initiative focuses on a better characterization of nearshore/offshore gradients.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes for offshore DRP concentrations and somewhat for nearshore DRP concentrations (this monitoring is not as frequent and does not have as long a record as offshore concentration monitoring).
	Individual lakes	Yes, however Canadian-led monitoring programs do not include Lake Michigan. Nearshore monitoring stations are monitored by different state and national programs, therefore these stations are specific to each nation's own shoreline. Additional sampling programs focus on (or will focus on) DRP concentrations in Lake Erie. Ohio EPA monitoring is limited to the Maumee River estuary, and US nearshore of the Western Basin, Sandusky Basin, and Central basin in Lake Erie. In February 2015, the Ohio Senate passed a bill that will establish a phosphorus monitoring program at many of Lake Erie's water intake facilities, but details of this program are currently in development.
	Subunit of lakes	Yes. In-lake concentration monitoring sites do have multiple sites within a lake subbasin and could be summarized by lake subbasin. Canadian-led monitoring programs do not include Lake Michigan. Additional sampling programs focus on (or will focus on) DRP concentrations in Lake Erie. Ohio EPA monitoring is limited to the Maumee River estuary, and US nearshore of the Western Basin, Sandusky Basin, and Central basin in Lake Erie. In February 2015, the Ohio Senate passed a bill that will establish a phosphorus monitoring program at many of Lake Erie's water intake facilities, but details of this are currently in development.
	Collection locations	Yes. GLNPO samples about 75 offshore sites once in the spring and summer each year and EC samples about 275 sites in the spring with each lake monitored every 2nd year. The EPA NCCA program sampled 248 sites in 2010. The OMOE visits 10-18 stations each year (lakes on a sampling rotation and program also targets connecting channels and Lake St. Clair). Ohio EPA sampled about 12-18 nearshore sites in Lake Erie from 2011-2013. The indicator description suggests a need to revisit the placement of stations and the depth resolution of

		sampling to better capture nearshore-offshore gradients on the system and improve the accuracy of basinwide average concentrations of both TP and DRP.
Regularly monitored	Is metric regularly monitored?	Yes. In-lake concentrations in offshore habitats are regularly monitored during annual spring and summer monitoring cruises by GLNPO and spring-only cruises by EC. Nearshore habitats are sampled with differing frequency. The OMOE Great Lakes Index stations are sampled within a year on a rotational basis (i.e., Lakes Ontario and Erie are sampled every three years while Lakes Superior and Huron are sampled every six years). The NCCA nearshore sites were sampled in 2010 and may be re-sampled every five years depending on continued funding. In 2011-2013, Ohio EPA nearshore sampling began after April 1 and continued through September 30. Samples from the Maumee River estuary, Western Basin and Sandusky Basin were collected on a bi-weekly basis while samples from the Central Basin were collected on a monthly basis.
	What is the monitoring cycle?	GLNPO: One sample per station each spring (before stratification) and summer (after stratification); EC: One sample per station each spring (before stratification); OMOE: Ontario and Erie stations sampled every three years, Superior and Huron every six years; NCAA EPA: Possibly every five years; Ohio EPA: Biweekly or monthly in early spring to end of summer.
Length of monitoring record	What is the period of record?	Varies with monitoring program. GLNPO offshore period of record is as long as 1983-present (although start date varies with lake and some seasonal cruises were skipped in early years); EC is 1974 to present (even older data are available, but these are not comprehensive and might not be comparable to post-1974 measures); EPA NCCA is 2010 only; OMOE nearshore is 2003-present; Ohio EPA nearshore monitoring is for 2011-2013 (with hopes of becoming an ongoing monitoring program).
	Any major gaps in record?	Minor gaps and regularly occurring gaps due to rotating sampling. There is no GLNPO concentration monitoring from 1994-1995. Both Canadian nearshore and offshore monitoring programs sample lakes on a rotational basis rather than annually.
Calibration and endpoints	Calibrated to account for natural variation across space and time	Within a program, concentration monitoring is highly standardized across years, seasons, sites, and lakes. Sample stations are consistently revisited.

	Calibrated within and across collection methods	Sampling and sample processing is calibrated within a sampling program. These programs use comparable analytic techniques, but there are differences in how samples are collected. For example GLNPO and OMOE sample at certain depths in the depth profile and include a water column composite sample, while EC focuses sampling surface water. Some of these differences can be accounted for in data summary approaches and therefore these concerns may be able to be addressed. EPA NCAA data are not currently available, limiting a complete assessment of collection methods. Ohio EPA uses a SeaBird® profiler (also used by GLNPO) or YSI® Pro Series meter and samples at various depths depending on stratification status. These sample depths are comparable to those collected by other programs.
	Has established endpoints, goals, criteria	Not specified in the indicator summary, but in-lake DRP concentrations could be averaged by subbasin or basin and compared to lake-specific concentration targets.
Owner and cost	Metric has "owner(s)" (Y/N)	Within-lake data DRP concentration data are maintained by various organizations: EPA GLNPO contact is Glenn Warren and data are available for download directly from the EPA CDX portal; EC contact is Alice Dove; EPA NCCA contact is Beth Hinchey Malloy; OMOE contact is Mary Thornburn; Ohio EPA contact is currently unknown, but a project document indicates data will be sent to the US EPA Water Quality Exchange.
	Estimated cost	No cost estimates were available for GLNPO, EC, and NCCA programs, but full contact information for Glenn Warren, Alice Dove, Beth Hinchey Malloy, and Mary Thornburn are provided. Ohio EPA estimates the cost of each DRP concentration sample at $23 (Ohio EPA 2014, page 10). However, it is not clear exactly what this estimate includes (e.g., just concentration determination or does it include the full cost of a sample including boat maintenance, use, and personnel, sample collection and storage, concentration testing, data entry and dissemination data, etc.).

PBTs in biota

Metric 1 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes whole fish

Description	**Data availability**	
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes. This indicator is nearly identical to SOLEC indicator "Contaminants in whole fish." Basin- and lake-level trends are summarized in the SOLEC (2011) report for individual contaminants. Top predator data available for all lakes, while rainbow smelt data is collected by Canada and not available for Lake Michigan.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. See Monitoring description below and SOLEC (2011).
	Individual lakes	Yes. See Monitoring description below and SOLEC (2011).
	Subunit of lakes	Yes. See Monitoring description below and SOLEC (2011). However, data are limited to the long-term monitoring sites so the capacity to assess trends within lakes is very limited.
	Collection locations	Yes. See Monitoring description below and SOLEC (2011). However, data are limited to the long-term monitoring sites so the capacity to assess trends within lakes is very limited. This can only be done at the limited number of sites within lakes.
Regularly monitored	Is metric regularly monitored?	Yes. Monitoring is primarily done by EC and US EPA. Twelve sites are monitored in Canada (~ three per lake); ten sites are monitored in t (two per lake on a rotating basis). Sites are consistent over time. More detailed spatial data are likely available through individual state agencies (i.e., MDEQ) and could be useful in identifying problem areas.
	What is the monitoring cycle?	Monitoring is conducted annually to every two years, focusing on open water habitats. Monitoring by state agencies will vary based on site and agency.
Length of monitoring record	What is the period of record?	1977 to present for EC and EPA.
	Any major gaps in record?	No. Gaps primarily occur early in the dataset, with no obvious gaps occurring in recent years. No rainbow smelt data available for Lake Michigan.
Calibration and endpoints	Calibrated to account for natural variation across space and time	No. Spatial and temporal variation in background contaminant levels is not well understood. Likely based on assumption that background levels are low and levels in the environment are primarily driven by human activities.
	Calibrated within and across collection methods	Yes. Samples are comparable within EC and EPA datasets, but difficult to compare across agencies because EC measures contaminants in individual fish while EPA measures contaminants in pooled samples. However, temporal patterns are consistent across agencies, suggesting this is not a major impediment.

	Has established endpoints, goals, criteria	Yes and no. This will depend on the specific contaminant of interest, but many contaminants have criteria set by the GLWQA.
Owner and cost	Metric has "owner(s)" (Y/N)	EC and EPA maintain data and it appears to be readily accessible (SOLEC 2011). Additional data sources may be more difficult to access. GLAHF have already assembled lake trout data from 1977-2009 for Superior, Huron, Michigan, and Ontario, and walleye data from 1977-2009 for Lake Erie.
	Estimated cost	Unknown. Likely possible to determine the total cost of the monitoring programs maintained by EPA and EC.
Indicator status	Have specific measures or components of the indicator been identified?	Yes and no. The indicator specifies that first order log-linear regression models of annual median concentrations should be used to estimate percent annual declines. Unclear exactly what contaminants should be tracked. Suggests organochloride pesticides, dioxins and furans, mercury and other trace metals (what other trace metals? this should be clarified), and also contaminants of emerging concern (polybrominated diethyl ethers, fluorinated chemicals, and synthetic musks). Should these contaminants of emerging concern be included? It is unclear how the trends of different contaminants should be integrated to develop an indicator score. Specific species of interest have also been identified (lake trout, walleye, rainbow smelt), but the June 2014 report suggests that additional species could also be considered (yellow perch, spottail shiner, largemouth bass). Should these additional species be included in the report?
	Has the indicator been identified and described?	Yes. I suspect the indicator will be very similar to the SOLEC 2011 report and the additional information discussed above will not be part of the indicator. Again, it is unclear how to integrate trends of multiple contaminants into a single indicator score.
	Has the spatial extent of the indicator been identified?	Yes. The description in the June 2014 report seems to suggest that the indicator should be based on the existing time series maintained by EC and EPA. Therefore, the spatial extent for the indicator is the basin (combination of all sites), individual lakes (combination of all sites within lake), and site specific (individual sampling locations).
	Has the temporal extent of the indicator been identified?	Yes. The indicator is defined by annual measurements over time. Therefore, the temporal extent is measurements are taken annually and the indicator is assessed as annual changes over time (hence first-order log-linear regressions with time as independent variable and contaminant level as dependent variable).

Metric 2 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes herring gull eggs. PBTs include organochloride pesticides, dioxins and furans, and trace metals (i.e., mercury).

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes. This indicator is nearly identical to SOLEC indicator "Contaminants in water birds." Basin- and lake-level trends are summarized in the SOLEC (2011) report for individual contaminants.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. See Monitoring description below and SOLEC (2011).
	Individual lakes	Yes. See Monitoring description below and SOLEC (2011).
	Subunit of lakes	Yes. See Monitoring description below and SOLEC (2011). However, data are limited to the long-term monitoring sites so the capacity to assess trends within lakes is very limited.
	Collection locations	Yes. See Monitoring description below and SOLEC (2011). However, data are limited to the long-term monitoring sites so the capacity to assess trends within lakes is very limited. This can only be done at the limited number of sites within lakes.
Regularly monitored	Is metric regularly monitored?	Yes. Monitoring is primarily done by the Ecotoxicology and Wildlife Health Division at EC. Herring gull nests have been monitored at fifteen sites across the basin and are consistent over time.
	What is the monitoring cycle?	Monitoring is conducted annually for herring gull eggs.
Length of monitoring record	What is the period of record?	1974 through present for herring gull.
	Any major gaps in record?	No, for herring gull eggs.
Calibration and endpoints	Calibrated to account for natural variation across space and time	No. Spatial and temporal variation in background contaminant levels is not well understood. Likely based on assumption that background levels are low and levels in the environment are primarily driven by human activities.
	Calibrated within and across collection methods	Yes. Consistent monitoring by a single agency throughout duration of monitoring period.
	Has established endpoints, goals,	Yes. Decreasing trends and contamination levels consistent with those from reference sites in Atlantic Canada and the Prairies (SOLEC 2011).

	criteria	
Owner and cost	Metric has "owner(s)" (Y/N)	EC maintains herring gull data and it is available.
	Estimated cost	Unknown. Likely possible to determine the total cost of the monitoring programs maintained by EC, though it will need to be determined to what extent this program is part of a large effort to assess herring gulls populations.
Indicator status	Have specific measures or components of the indicator been identified?	Yes and no. More clearly defined than fish analyses in that PCBs, organochlorine pesticides, dioxins and furans, mercury and other trace metals, and PBDEs should be evaluated and continue to be monitored, but still the challenge of how to integrate multiple contaminant trends into a single indicator value applies.
	Has the indicator been identified and described?	Yes. I suspect the indicator will be very similar to the SOLEC 2011 report for herring gull eggs. Again, it is unclear how to integrate trends of multiple contaminants into a single indicator score.
	Has the spatial extent of the indicator been identified?	Yes. The description in the June 2014 report seems to suggest that the indicator should be based on the existing time series maintained by EC. Therefore, the spatial extent for the indicator is the basin (combination of all sites), individual lakes (combination of all sites within lake), and site specific (individual sampling locations).
	Has the temporal extent of the indicator been identified?	Yes. The indicator is defined by annual measurements over time. Therefore, the temporal extent is measurements are taken annually and the indicator is assessed as annual changes over time (hence first-order log-linear regressions with time as independent variable and contaminant level as dependent variable).

Metric 3 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes bald eagles. PBTs include organochloride pesticides, dioxins and furans, and trace metals (i.e., mercury).

Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. There is not a systematic monitoring program for bald eagle contaminants like there are for Herring Gulls. In the SOLEC 2009 report they discuss some contaminant trends but they do not present the figures. Unclear what is actually available until Bowerman is contacted.
Rigorously monitored to report statistically meaningful results	Entire basin	Unclear for bald eagles, most recent updating was in SOLEC 2005, but included in SOLEC 2009. SOLEC reports discuss efforts of the state agencies; however, these are likely inconsistent in time and space and may present a challenge when integrated into the indicator.
	Individual lakes	Unclear for bald eagles, most recent updating was in SOLEC 2005, but included in SOLEC 2009. SOLEC reports discuss efforts of the state agencies; however, these are likely inconsistent in time and space and may present a challenge when integrated into the indicator.
	Subunit of lakes	Unclear for bald eagles, most recent updating was in SOLEC 2005, but included in SOLEC 2009. SOLEC reports discuss efforts of the state agencies; however, these are likely inconsistent in time and space and may present a challenge when integrated into the indicator.
	Collection locations	Unclear for bald eagles, most recent updating was in SOLEC 2005, but included in SOLEC 2009. SOLEC reports discuss efforts of the state agencies; however, these are likely inconsistent in time and space and may present a challenge when integrated into the indicator.
Regularly monitored	Is metric regularly monitored?	Unclear. Monitoring of bald eagles does not appear to be done systematically across the basin like whole fish tissues and herring gulls. Some historical data are available (Bowerman is the contact); however, the capacity to integrate these within an indicator score is unclear.
	What is the monitoring cycle?	Unclear for bald eagles, but appears to be conducted in five year intervals with gaps between monitoring efforts.
Length of monitoring record	What is the period of record?	Unclear for bald eagle, but Roe et al. 2008 report indicates data is available for 1987-1992 and 1990-2003 for Michigan, and SOLEC 2005 and 2009 discuss trends in nest productivity back to the 1960's. It is less clear how this monitoring has continued and how it is conducted. SOLEC 2009 report does present figure of

		contaminant trends but states they are stable or decreasing so they must be available. W. Bowerman should be able to clarify this easily.
	Any major gaps in record?	Yes, for bald eagles. This is driven by lack of consistency across space and time.
Calibration and endpoints	Calibrated to account for natural variation across space and time	No. Spatial and temporal variation in background contaminant levels is not well understood. Likely based on assumption that background levels are low and levels in the environment are primarily driven by human activities.
	Calibrated within and across collection methods	No. SOLEC 2009 report discusses reporting from multiple state agencies, but suggests only a subset of these will continue to monitor due to budgetary restrictions. It is not clear how monitoring has progressed in the past 5-10 years since the SOLEC 2009 report is primarily based on data up to 2005.
	Has established endpoints, goals, criteria	Yes. Decreasing trends and contamination levels consistent with those from reference sites in Atlantic Canada and the Prairies (SOLEC 2011).
Owner and cost	Metric has "owner(s)" (Y/N)	Yes. Bowerman appears to be contact for bald eagle data.
	Estimated cost	Unknown
Indicator status	Have specific measures or components of the indicator been identified?	Yes and no. Bald eagle component appears similar to herring gull though it is less clear how this should be calculated as this has not been an indicator in previous SOLEC reports. For instance, in what tissue should bald eagle contaminants be tracked? Appears to be blood, but this is not specified in the report. The June 2014 report refers to the SOLEC 2014 report as a source of guidance; however, this report does not exist due to the shift in the SOLEC cycle associated with the resigning of the GLWQA.
	Has the indicator been identified and described?	No. The indicator is poorly described for bald eagles in terms of contaminants as previous SOLEC reports focus on nest productivity and deformities. Again, it is unclear how to integrate trends of multiple contaminants into a single indicator score.
	Has the spatial extent of the indicator been identified?	Yes. The spatial extent of bald eagle monitoring is unclear. Appears to be good data available from Michigan but other locations are less consistently monitored and may have stopped due to budgetary restrictions.
	Has the temporal extent of the indicator been identified?	Yes. For bald eagles, there are historical datasets available, but it is unclear how this monitoring has continued into the future. MDEQ report (Roe et al 2008) has information from 1987-1992, 1999-2003.

Harmful and nuisance algae blooms

Metric 1 - Metric measures frequency and magnitude of harmful algae blooms, assigning scores of good, moderate, and severe. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds. Metric focuses on the concentrations of Microcystin-LR or the concentrations of chlorophyll a and communities dominated by cyanobacterial species.

Description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Data is primarily focused around trouble locations (i.e., Lake Erie and Ontario, potentially Green Bay and Saginaw Bay). Very limited data is available for Lake Superior, Lake Huron, and Lake Michigan. Additional datasets are maintained by independent research projects that focus on small geographic areas. Could be additional information available for water treatment facilities throughout the basin but the data appear to be scattered and not easily accessible.
Rigorously monitored to report statistically meaningful results	Entire basin	No. However, analyzing satellite images could provide coarse metrics of magnitude and extent of algal blooms.
	Individual lakes	No. Some capacity to calculate for Lake Erie and Ontario. Finding specifics of monitoring program is difficult. Most of the links are dead and do not redirect to anywhere.
	Subunit of lakes	No. Some potential in Lake Erie, especially with focus on Western Basin.
	Collection locations	Potentially. For instance, the Ohio Environmental Protection Agency reports results of water sampling conducted on water to be used for drinking water. It seems likely additional information will be available for other lakes and locations where water monitoring is required. Availability of offshore data appears to be limited.
Regularly monitored	Is metric regularly monitored?	Yes and no. There is no systematic monitoring program at the basin level; however, water treatment facilities for drinking water should have site specific data at fairly high frequency. How accessible this information is remains unclear. Specifics of Environmental Canada and EPA monitoring programs and what types and amount of data are available is unclear and will require discussions with Sue Watson and Greg Boyer. Following the water quality issues near Toledo in 2014, there will be a network of continuously monitoring buoys on the west side of Lake Erie. Additional integrations across the basin should be expected in the next few years.

	What is the monitoring cycle?	Very inconsistent since these events are episodic and highly variable in space and time. Some of western Lake Erie monitoring is done biweekly from April through October since 2002. Monitoring cycle of other programs is unclear. Water treatment facilities appear to monitor fairly frequently (i.e., weekly for locations on Lake Erie).
Length of monitoring record	What is the period of record?	Difficult to discern, but appears to be very little prior to 2000. Ohio EPA reports monitoring of water intakes, Lake Erie, and Ohio Beaches for Microcystin. Other states have similar beach monitoring programs but they are primarily focused on E. coli based what is available on the internet.
	Any major gaps in record?	Yes. Across both space and time due to the lack of comprehensive monitoring program and the diversity of data sources (e.g., agencies, municipalities, researchers).
Calibration and endpoints	Calibrated to account for natural variation across space and time	No.
	Calibrated within and across collection methods	No. Highly variable across data collectors. Many different techniques. Potentially some capacity to make comparisons across water treatment facilities.
	Has established endpoints, goals, criteria	Yes. The score structure of Severe, Moderate, and Good has clearly identified threshold criteria; however, gathering the appropriate data to calculate HNA indicators will be challenging.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes. Environmental Canada. Watson and Boyer should be contacted to further clarify what is available. Water treatment facility datasets are variable. Some (e.g., Ohio EPA) list detailed measurements on the internet; however, most appear to offer only summaries, such as, Microcystin did not exceed this threshold, etc.
	Estimated cost	Unknown.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The three components of this indicator (harmful algal blooms, nuisance algal blooms, and excessive algal abundance) have clear criteria set to assign scores of severe, moderate, and good. Thresholds have been identified. Overall score for a water body is determined by the maximum score of any of the three measures (good = 1, moderate = 2, severe = 3).

	Has the indicator been identified and described?	Yes, but the greatest challenge is the lack of a comprehensive, consistent monitoring program across the basin. It should be possible to calculate indicator values for Lakes Erie and Ontario based on collaborations with Sue Watson and Greg Boyer, but assessments for upper lakes will likely need to be done qualitatively. This may not be a major short coming as these areas are likely less impacted by HNAs.
	Has the spatial extent of the indicator been identified?	Yes. The June 2014 report indicates that this indicator should be calculated at the lake level; however, depending on the data available, it may also be possible to focus on specific areas of concern with greater data availability (e.g., Toledo area, Hamilton Harbour).
	Has the temporal extent of the indicator been identified?	Yes and no. The three components of this indicator suggest it should be calculated on an annual basis for each lake; however, the challenge will be determining the frequency to monitor water quality parameters due to the high spatial and temporal variability associated with HNAs. When absent, biweekly data may be appropriate; when present, more frequent monitoring will need to be conducted to accurately assess if the thresholds of indicator scores have been exceeded.

Metric 2 - Metric measures frequency and magnitude of nuisance algae blooms, assigning scores of good, moderate, and severe. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds. Metric focuses on the concentrations of chlorophyll a and levels of common algal odor compounds or occurrence of a "significant number of beach closings."

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Data is primarily focused around trouble locations (i.e., Lake Erie and Ontario, potentially Green Bay and Saginaw Bay). Limited data is available for Lake Superior, Lake Huron, and Lake Michigan. Additional datasets are maintained by independent research projects that focus on small geographic areas. Could be additional information available for water treatment facilities throughout the basin but the data appear to be scattered and not easily accessible.
Rigorously monitored to report statistically meaningful results	Entire basin	No. However, analyzing satellite images could provide coarse metrics of magnitude and extent of algal blooms.
	Individual lakes	No. Some capacity to calculate for Lake Erie and Ontario. Finding specifics of monitoring program is difficult. Most of the links are dead and do not redirect to anywhere.
	Subunit of lakes	No. Some potential in Lake Erie, especially with focus on Western Basin.
	Collection locations	Potentially. For instance, the Ohio Environmental Protection Agency reports results of water sampling conducted on water to be used for drinking water. It seems likely additional information will be available for other lakes and locations where water monitoring is required. Availability of offshore data appears to be limited.
Regularly monitored	Is metric regularly monitored?	Yes and no. There is no systematic monitoring program at the basin level; however, water treatment facilities for drinking water should have site specific data at fairly high frequency. Specifics of Environmental Canada and EPA monitoring programs and what types and amount of data are available is unclear and will require discussions with Sue Watson and Greg Boyer.
	What is the monitoring cycle?	Very inconsistent since these events are episodic and highly variable in space and time. Some of western Lake Erie monitoring is done biweekly from April through October since 2002. Monitoring cycle of other programs is unclear. Water treatment facilities appear to monitor fairly frequently (i.e., weekly for locations on

		Lake Erie).
Length of monitoring record	What is the period of record?	Difficult to discern, but appears to be very little prior to 2000. There is some monitoring that has been occurring in Ohio beginning in 2011. Michigan and other states have been monitoring beaches and have records on beach closures; however, these primarily due to E. coli measurements not excessive algal material.
	Any major gaps in record?	Yes. Across both space and time due to the lack of comprehensive monitoring program and the diversity of data sources (e.g., agencies, municipalities, researchers).
Calibration and endpoints	Calibrated to account for natural variation across space and time	No.
	Calibrated within and across collection methods	No. Highly variable across data collectors. Many different techniques. Potentially some capacity to make comparisons across water treatment facilities.
	Has established endpoints, goals, criteria	Yes. The score structure of Severe, Moderate, and Good has clearly identified threshold criteria; however, gathering the appropriate data to calculate HNA indicators will be challenging.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes. Environmental Canada. Watson and Boyer should be contacted to further clarify what is available. Water treatment facility datasets are variable. Some (e.g., Ohio EPA) list detailed measurements on the internet; however, most appear to offer only summaries, such as, Microcystin did not exceed this threshold, etc.
	Estimated cost	Unknown.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The three components of this indicator (harmful algal blooms, nuisance algal blooms, and excessive algal abundance) have clear criteria set to assign scores of severe, moderate, and good. Thresholds have been identified. Overall score for a water body is determined by the maximum score of any of the three measures (good = 1, moderate = 2, severe = 3).
	Has the indicator been identified and described?	Yes, but the greatest challenge is the lack of a comprehensive, consistent monitoring program across the basin. It should be possible to calculate indicator values for Lakes Erie and Ontario based on collaborations with Sue Watson and Greg Boyer, but assessments for upper lakes will likely need to be done qualitatively. This may not be a major short coming as these areas are likely less

		impacted by HNAs.
	Has the spatial extent of the indicator been identified?	Yes. The June 2014 report indicates that this indicator should be calculated at the lake level; however, depending on the data available, it may also be possible to focus on specific areas of concern with greater data availability (e.g., Toledo area, Hamilton Harbour).
	Has the temporal extent of the indicator been identified?	Yes and no. The three components of this indicator suggest it should be calculated on an annual basis for each lake; however, the challenge will be determining the frequency to monitor water quality parameters due to the high spatial and temporal variability associated with HNAs. When absent, biweekly data may be appropriate; when present, more frequent monitoring will need to be conducted to accurately assess if thresholds of indicator scores have been exceeded.

Metric 3 - Indicator measures frequency and magnitude of harmful and nuisance algae blooms, assigning scores of good, moderate, and severe for 1) harmful algal blooms, 2) nuisance algal blooms, and 3) excessive algal abundance. Assignment of scores are based on specific criteria about how often specific algal concentrations exceed defined thresholds.

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Data is primarily focused around trouble locations (i.e., Lake Erie and Ontario, also Green Bay and Saginaw Bay?). Limited data is available for Lake Superior, Lake Huron, and Lake Michigan. Additional datasets are maintained by independent research projects that focus on small geographic areas. Could be additional information available for water treatment facilities throughout the basin but the data appear to be scattered and not easily accessible.
Rigorously monitored to report statistically meaningful results	Entire basin	No. However, analyzing satellite images could provide coarse metrics of magnitude and extent of algal blooms.
	Individual lakes	No. Some capacity to calculate for Lake Erie and Ontario. Finding specifics of monitoring program is difficult. Most of the links are dead and do not redirect to anywhere.
	Subunit of lakes	No. Some potential in Lake Erie, especially with focus on Western Basin.
	Collection locations	Potentially. For instance, the Ohio Environmental Protection Agency reports results of water sampling conducted on water to be used for drinking water. It seems likely additional information will be available for other lakes and locations where water monitoring is required. Availability of offshore data appears to be limited.
Regularly monitored	Is metric regularly monitored?	Yes and no. There is no systematic monitoring program at the basin level; however, water treatment facilities for drinking water should have site specific data at fairly high frequency. Specifics of Environmental Canada and EPA monitoring programs and what types and amount of data are available is unclear and will require discussions with Sue Watson and Greg Boyer.
	What is the monitoring cycle?	Very inconsistent since these events are episodic and highly variable in space and time. Some of western Lake Erie monitoring is done biweekly from April through October since 2002. Monitoring cycle of other programs is unclear. Water treatment facilities appear to monitor fairly frequently (i.e., weekly for locations on Lake Erie).

Length of monitoring record	What is the period of record?	Difficult to discern, but appears to be very little prior to 2000.
	Any major gaps in record?	Yes. Across both space and time due to the lack of comprehensive monitoring program and the diversity of data sources (e.g., agencies, municipalities, researchers).
Calibration and endpoints	Calibrated to account for natural variation across space and time	No.
	Calibrated within and across collection methods	No. Highly variable across data collectors. Many different techniques. Potentially some capacity to make comparisons across water treatment facilities.
	Has established endpoints, goals, criteria	Yes. The score structure of Severe, Moderate, and Good has clearly identified threshold criteria; however, gathering the appropriate data to calculate HNA indicators will be challenging.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes. Environmental Canada. Watson and Boyer should be contacted to further clarify what is available. Water treatment facility datasets are variable. Some (e.g., Ohio EPA) list detailed measurements on the internet; however, most appear to offer only summaries, such as, Microcystin did not exceed this threshold, etc.
	Estimated cost	Unknown.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The three components of this indicator (harmful algal blooms, nuisance algal blooms, and excessive algal abundance) have clear criteria set to assign scores of severe, moderate, and good. Overall score for a water body is determined by the maximum score of any of the three measures (good = 1, moderate = 2, severe = 3).
	Has the indicator been identified and described?	Yes, but the greatest challenge is the lack of a comprehensive, consistent monitoring program across the basin. It should be possible to calculate indicator values for Lakes Erie and Ontario based on collaborations with Sue Watson and Greg Boyer, but assessments for upper lakes will likely need to be done qualitatively. This may not be a major short coming as these areas are likely less impacted by HNAs.

	Has the spatial extent of the indicator been identified?	Yes. The June 2014 report indicates that this indicator should be calculated at the lake level; however, depending on the data available, it may also be possible to focus on specific areas of concern with greater data availability (e.g., Toledo area, Hamilton Harbor).
	Has the temporal extent of the indicator been identified?	Yes and no. The three components of this indicator suggest it should be calculated on an annual basis for each lake; however, the challenge will be determining the frequency to monitor water quality parameters due to the high spatial and temporal variability associated with HNAs. When absent, biweekly data may be appropriate; when present, more frequent monitoring will need to be conducted to accurately assess if the thresholds of indicator scores have been exceeded.

Fish Species of Interest

Metric 1 - Metric measures status and trends in population abundance of cold water species and includes lake trout and lake whitefish. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes. Lake trout and lake whitefish are well studied throughout the basin and significant effort has been devoted to develop population models to estimate demographics for these species. These are focused in 1836 and 1842 treaty waters (upper Michigan and Huron, lower Superior). Much of this information is available by management units within lakes. In addition to modeling efforts, state agencies across the basin have developed monitoring programs specifically designed to assess populations of lake trout and to a lesser extent lake whitefish.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes.
	Individual lakes	Yes.
	Subunit of lakes	Yes. Typically these are broken up by management units designated through GLFC Lake Technical Committees.
	Collection locations	Yes.
Regularly monitored	Is metric regularly monitored?	Yes. Fish community surveys throughout the basin are typically conducted once annually. These surveys tend to target economically important sport fish, though additional non-target species are also captured and biological data is usually recorded (especially in recent years). If population models exist for a species, those are typically updated on an annual to semi-annual basis based on recent catch statistics.
	What is the monitoring cycle?	Annually.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	No. Lake Trout and Lake Whitefish have detailed records and sophisticated statistical catch-at-age models to assess status and trends.
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes. Clear management objectives focused on specific management units or geographical areas are available for Lake Trout and Lake Whitefish.
	Calibrated within and across	Yes. GLFC Technical Committees have attempted to overcome these challenges

	collection methods	through species-specific task forces within each lake for lake trout and lake whitefish. Comparisons across lakes will be more challenging but likely possible for these species since so much effort has been devoted to characterizing population dynamics of these species.
	Has established endpoints, goals, criteria	Yes. These are established by experts within the GLFC Lake Technical Committees and will vary by lake and management unit.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are typically available through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 2 - Metric measures status and trends in recruitment of the cold water species, lake trout and lake whitefish. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes. Lake trout and lake whitefish are well studied throughout the basin and significant efforts have been devoted to develop population models to estimate demographics for these species. These are focused in 1836 and 1842 treaty waters (upper Michigan and Huron, lower Superior). Much of this information is available by management units within lakes. Assessment of lake trout recruitment is challenging since they are regularly stocked throughout the Great Lakes, so this metric should be clarified to differentiate between natural reproduction/recruitment and stocking.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes.
	Individual lakes	Yes.
	Subunit of lakes	Yes. These are broken up by management units designated by the GLFC.
	Collection locations	Yes.
Regularly monitored	Is metric regularly monitored?	Yes. Fish community surveys throughout the basin are typically conducted once annually. These surveys tend to target economically important sport fish, though additional non-target species are also captured and biological data is usually recorded (especially in recent years). If population models exist for a species, those are typically updated on an annual to semi-annual basis based on recent catch statistics.
	What is the monitoring cycle?	Annually. Though some surveys are conducted multiple times throughout a year, primarily those targeting dynamics of early life history stages.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	No. Lake trout and lake whitefish have detailed records and sophisticated statistical catch-at-age models which are default should also provide indices of recruitment.
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes. Clear management objectives focused on specific management units or geographical areas are available for lake trout and lake whitefish.
	Calibrated within and across collection	Yes. GLFC Committees have attempted to overcome these challenges through species-specific task forces within each lake for lake trout and lake whitefish. Comparisons across

	methods	lakes will be more challenging but likely possible for these species since so much effort has been devoted to characterizing population dynamics of these species.
	Has established endpoints, goals, criteria	Yes. These are established by experts within the GLFC Lake Technical Committees and will vary by lake and management unit.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are typically available through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 3 - Metric measures status and trends in population abundance of cool water species and includes walleye. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes and no. Walleye are well studied within Lake Erie; however, information from other lakes is primary limited to specific geographic locations (e.g., Saginaw Bay, Green Bay, and Bays du Noc). For some of these locations, population models exist and can be used to develop scores for this metric.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. Regularly included in Lake Technical Committee reports.
	Individual lakes	Yes. Regularly included in Lake Technical Committee reports.
	Subunit of lakes	Yes. Regularly included in Lake Technical Committee reports.
	Collection locations	Yes. Regularly included in Lake Technical Committee reports.
Regularly monitored	Is metric regularly monitored?	Yes. Fish community surveys throughout the basin are typically conducted once annually. For walleye, this is typically done with a gillnet survey to assess adult populations, while trawl surveys are done to assess early life history stages. These are conducted in Lake Erie, Saginaw Bay, and Bay du Noc. Not clear what Wisconsin DNR does in Green Bay, but information may be available as part of yellow perch assessments.
	What is the monitoring cycle?	Annually. Though some surveys are conducted multiple times throughout a year, primarily those targeting dynamics of early life history stages.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	No. In locations where there are fisheries for walleye, most agencies across the basin have developed monitoring programs that are fairly consistent across time with minimal gaps in the assessments.
Calibration and endpoints	Calibrated to account for natural variation across space and time	No. There is likely more value in comparing the temporal trends within a population when assessing the status and trends and a response to a management action. Determining the natural spatial and temporal variation would be challenging.
	Calibrated within and across collection methods	Yes. The GLFC Technical Committees have attempted to overcome these challenges through species-specific task forces within each lake for walleye when population models exist; however, typically for walleye these are based on a specific population not the whole lake. Combining data from multiple surveys with different gears and experimental designs will be challenging.

	Has established endpoints, goals, criteria	Yes. If available, these are established by experts within the GLFC Technical Committees. For walleye, these are often based on specific state agencies. For instance, Michigan DNR has goals for the Saginaw Bay population and adjusts stocking rates based on abundance and recruitment.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 4 - Metric measures status and trends in recruitment of the cool water species walleye. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	Yes and no. Walleye are well studied within Lake Erie; however, information from other lakes is primary limited to specific geographic locations (e.g., Saginaw Bay, Green Bay, and Bays du Noc). For some of these locations, population models exist and can be used to develop scores for this metric. In other locations, fish community surveys can be used to assess recruitment through analyses of CPUE. Locations with trawl surveys will likely provide the best opportunities to assess recruitment because they tend to target younger life stages.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. Regularly included in Lake Technical Committee reports.
	Individual lakes	Yes. Regularly included in Lake Technical Committee reports.
	Subunit of lakes	Yes. Regularly included in Lake Technical Committee reports.
	Collection locations	Yes. Regularly included in Lake Technical Committee reports.
Regularly monitored	Is metric regularly monitored?	Yes. Fish community surveys throughout the basin are typically conducted once annually. For walleye, this is typically done with a gillnet survey to assess adult populations, while trawl surveys are done to assess early life history stages. These are conducted in Lake Erie, Saginaw Bay, and Bay du Noc. Not clear what Wisconsin DNR does in Green Bay, but information may be available as part of yellow perch assessments.
	What is the monitoring cycle?	Annually. Though some surveys are conducted multiple times throughout a year, primarily those targeting dynamics of early life history stages.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	No. In locations where there are fisheries for walleye, most agencies across the basin have developed monitoring programs that are fairly consistent across time with minimal gaps in the assessments.
Calibration and endpoints	Calibrated to account for natural variation across space and time	No. There is likely more value in comparing the temporal trends within a population when assessing the status and trends and a response to a management action. Determining the natural spatial and temporal variation would be challenging.
	Calibrated within and across collection methods	Yes. GLFC Technical Committees have attempted to overcome these challenges through species-specific task forces within each lake for walleye when population models exist; however, typically for walleye these are based on a specific population not the whole lake.

		Combining data from multiple surveys with different gears and experimental designs will be challenging.
	Has established endpoints, goals, criteria	Yes. If available, these are established by experts within the GLFC Lake Technical Committees. For walleye, these are often based on specific state agencies. For instance, Michigan DNR has goals for the Saginaw Bay population and adjusts stocking rates based on abundance and recruitment.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 5 - Metric measures status and trends in population abundance for lake sturgeon. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Lake sturgeon data is primarily associated with specific populations (Lake St. Claire, western Lake Michigan). This species differs from others on the list as management actions focus on conservation/restoration objectives since there is limited harvest. Lake sturgeon is consistently included in GLFC State of the Lake reports. There is a high degree of variation across and within lakes in how sturgeon is assessed. Trends in adult fish populations are often tracked as the number of adults in spawning runs. There does not appear to be any population models for lake sturgeon in the Great Lakes. Lake sturgeon was included as an indicator in the most recent SOLEC report which summarizes available data and sources.
Rigorously monitored to report statistically meaningful results	Entire basin	Yes. Presence of lake sturgeon spawning population has been determined previously. Measurements of the number of adult spawners can be used to determine CPUE trends in adult abundance.
	Individual lakes	Yes.
	Subunit of lakes	Yes.
	Collection locations	Yes. Broken down by spawning tributaries.
Regularly monitored	Is metric regularly monitored?	Yes and no. There is a high amount of variation in the amount of monitoring effort to assess lake sturgeon populations across tributaries.
	What is the monitoring cycle?	Annually to very irregular. Depends on the tributary.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	Yes. SOLEC 2011 indicates that efforts are currently underway to develop monitoring recommendations for lake sturgeon but these have not been completed yet. Much of the current data is based on documenting remnant populations but less effort has been made to characterize the size of these populations.

Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes and no. There have been efforts to characterize historic distributions of lake sturgeon that suggest spawning was widespread across the basin. Less is known about the relative size of these populations. Currently, there are a few large spawning populations across the basin, but most remnant populations are small.
	Calibrated within and across collection methods	No. High amount of variation.
	Has established endpoints, goals, criteria	Yes. Fish community objectives for lake sturgeon focus on improving populations and recruitment with the end goal of removing them from them from the threatened/endangered list. What will be required for that to happen be not clearly defined.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.

	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 6 - Metric measures status and trends in recruitment of lake sturgeon. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Lake sturgeon data is primarily associated with specific populations (Lake St. Claire, western Lake Michigan) and focuses on adult populations but less is known about juveniles, limiting the ability to assess recruitment. This species differs from others on the list as management actions focus on conservation/restoration objectives since there is limited harvest. Some tributaries have information on larval lake sturgeon over time, but in general, annual monitoring appears to be uncommon.
Rigorously monitored to report statistically meaningful results	Entire basin	No. Assessment of larval and age-0 lake sturgeon in tributaries is limited to a few locations.
	Individual lakes	No. Much of the monitoring of early lake sturgeon life stages is done in snapshots to confirm spawning population. Less is known about trends over time other than a few locations.
	Subunit of lakes	No. See above.
	Collection locations	No. See above.
Regularly monitored	Is metric regularly monitored?	No. SOLEC 2011 indicates the more monitoring is needed for juvenile life stages because it is currently poorly understood. Exceptions include Huron-Erie Corridor and Lower Fox River System in Wisconsin.
	What is the monitoring cycle?	When surveys exist, they tend to be done annually. For most tributaries across the basin, data appears to be limited to a few years or less, and is associated with confirming spawning.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. However, this is a currently an important topic in the Great Lakes and monitoring should be increasing in upcoming years.
	Any major gaps in record?	Yes. Very limited data across years to assess temporal trends.
Calibration and endpoints	Calibrated to account for natural variation across space and time	Yes and no. There have been efforts to characterize historic distributions of lake sturgeon that suggest spawning was widespread across the basin. Less is known about the relative size of these populations or their relative recruitment. Currently, there are a few large spawning populations across the basin, but most remnant populations are small. It seems likely that recruitment patterns will match the adult population trends if data are collected.
	Calibrated within and across collection methods	No. High amount of variation.
	Has established	Yes. Fish community objectives for lake sturgeon focus on

	endpoints, goals, criteria	improving populations and recruitment with the end goal of removing them from them from the threatened/endangered list. What will be required for that to happen be not clearly defined.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 7 - Metric measures status and trends in population abundance for warm water species, including northern pike, and smallmouth bass/largemouth bass. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		Data availability
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Very little is known about northern pike and smallmouth bass/largemouth bass throughout the basin, though there is catch data available through fish community surveys in specific locations that can be used to evaluate trends in CPUE.
Rigorously monitored to report statistically meaningful results	Entire basin	No.
	Individual lakes	No.
	Subunit of lakes	Maybe. If these species are captured in surveys targeting other species, there is some potential to assess temporal trends at those locations.
	Collection locations	Maybe. If these species are captured in surveys targeting other species, there is some potential to assess temporal trends at those locations.
Regularly monitored	Is metric regularly monitored?	No. Population models do not exist for northern pike and bass; therefore, assessing trends will need to be based solely on catch-per-unit-effort trends within individual surveys.
	What is the monitoring cycle?	Annually. Though some surveys are conducted multiple times throughout a year, primarily those targeting dynamics of early life history stages.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	Yes. Very little is known about these species in the Great Lakes and very few surveys exist that target these species. Some exceptions may include St. Lawrence (northern pike), and Lakes Erie and St. Claire (bass).
Calibration and endpoints	Calibrated to account for natural variation across space and time	No.
	Calibrated within and across collection methods	No.
	Has established endpoints, goals, criteria	No.
Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through

		technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Metric 8 - Metric measures status and trends in recruitment of northern pike, and smallmouth bass/largemouth bass. This indicator emphasizes model generated estimates over fisheries surveys or commercial catch statistics.

Data description		**Data availability**
Comprehensive data across the basin	Is there comprehensive coverage of data for this metric?	No. Very little is known about northern pike and smallmouth bass/largemouth bass throughout the basin, though there is catch data available through some fish community surveys in specific locations.
Rigorously monitored to report statistically meaningful results	Entire basin	No.
	Individual lakes	No.
	Subunit of lakes	Maybe. If these species are captured in surveys targeting other species, there is some potential to assess temporal trends at those locations.
	Collection locations	Maybe. If these species are captured in surveys targeting other species, there is some potential to assess temporal trends at those locations.
Regularly monitored	Is metric regularly monitored?	No. Population models do not exist for Northern Pike and Bass; therefore, assessing trends will need to be based solely on catch-per-unit-effort trends within individual surveys.
	What is the monitoring cycle?	Annually. Though some surveys are conducted multiple times throughout a year, primarily those targeting dynamics of early life history stages.
Length of monitoring record	What is the period of record?	Varies significantly by survey and agency. Most surveys have been maintained for at least 20+ years and up to 40+ (even greater for commercial landings in some locations); however, sampling specifics and experimental design often vary across time series. This highlights the importance of model generated outputs to assess status and trends.
	Any major gaps in record?	Yes. Very little is known about these species in the Great Lakes and very few surveys exist that target these species. Some exceptions may include St. Lawrence (Northern Pike), and Lakes Erie and St. Claire (Bass).
Calibration and endpoints	Calibrated to account for natural variation across space and time	No.
	Calibrated within and across collection methods	No.
	Has established endpoints, goals, criteria	No.

Owner and cost	Metric has "owner(s)" (Y/N)	Yes and no. Depends on the level of detail desired. General trends are available for some species through technical reports that are widely available; however, raw data will be maintained by specific agencies throughout the basin.
	Estimated cost	Calculating this is very complicated and will require accounting for the resources (boats, gear, people, etc.) necessary to collect the data and develop the models. Additionally, there is not one contact or agency that assesses this metric as multiple state agencies, federal agencies, tribes, and NGOs are involved in developing the population estimates.
Indicator status	Have specific measures or components of the indicator been identified?	Yes. The metric focuses on trends in adult abundance and recruitment, focusing on: 1) model generated outputs 2) CPUE trends in fishery independent surveys, and 3) CPUE from commercial and angler fisheries. Though the June 2014 report is very vague, an additional, more detailed description has been provided to several of the Lake Technical Committees and highlights how individual species should be scored. Scores range from 0 to ten and are based on the current population relative to various quartiles of historical trends. Ten is good and indicates high abundance, 0 indicates that the species is absent from area.
	Has the indicator been identified and described?	Yes. This indicator is based on fisheries experts of the Lake Technical Committees of the GLFC. How this is done is not laid out in the June 2014 report, but it will entail some type of "standard scoring" based on defined ranges of fish stocks within and across lakes. In general, it seems that developing scoring within lakes will be done by the experts on the various technical committees.
	Has the spatial extent of the indicator been identified?	No. Language is unclear, but it seems it will based on the recommendations of the Lake Technical Committees and will vary by species as not all fish species of interest are distributed across all lakes or within all habitats within a lake.
	Has the temporal extent of the indicator been identified?	No. Suggested to occur approximately every five years to correspond to GLFC State of the Lakes reports in April 2013 data availability report. It is implied that calculation of these indicators will go as far back in time as available data permits.

Appendix C: Summary of Metric Results from Indicator Leads

Summary Parameter	Metric Result
Indicator	Fish Species of Interest
Chosen Metric	Lake trout/lake whitefish adult abundance
Main Reason for Choice	Reflects multiple stressors in multiple ways
Ability to be interlinked with other metrics from other indicators	Stand-alone, more powerful if used in conjunction with other indicators (& fish metrics)
Reporting structure	Good representative of oligotrophic habitats
Operationalization ability (if included)	Abundance trends for each sp. for each lake

Summary Parameter	Metric Result
Indicator	Nutrients-P Loads & In-Lake Concentrations
Chosen Metric	Total phosphorus concentration in lakes
Main Reason for Choice	Most easily understood by lay audience
Ability to be interlinked with other metrics from other indicators	NOT stand-alone, more powerful if used in conjunction with HABs, Water Temperature
Reporting structure	Not a straightforward indicator (invasive sp. & nearshore shunt)
Operationalization ability (if included)	TP-lakes public; TP-tributaries stakeholders

Summary Parameter	Metric Result
Indicator	PBTs in Biota
Chosen Metric	PBTs in Whole Fish
Main Reason for Choice	Readily measured, links to human health
Ability to be interlinked with other metrics from other indicators	Stand-alone, influenced by other factors, related to CMC
Reporting structure	Can include new contaminants; archiving
Operationalization ability (if included)	Trends overall, by lake, recent changes

Summary Parameter	Metric Result
Indicator	Harmful and Nuisance Algal Blooms
Chosen Metric	Planktonic blooms (nuisance)
Main Reason for Choice	Relies on satellite imagery

Ability to be interlinked with other metrics from other indicators	Combined with Water Temperature, Nutrient Loads
Reporting structure	Good for identifying bloom conditions
Operationalization ability (if included)	Visual representation, annual length duration & maximum extent

Summary Parameter	Metric Result
Indicator	Water Levels
Chosen Metric	Long-term water level variability
Main Reason for Choice	Directly impacts ecological endpoints
Ability to be interlinked with other metrics from other indicators	Linked with Coastal Ecosystems (wetland migration, habitats)
Reporting structure	Very high quality, long-term data
Operationalization ability (if included)	Graphical summary (water level dashboard)

Summary Parameter	Metric Result
Indicator	Water Temperature
Chosen Metric	Max ice cover
Main Reason for Choice	Highly interpretable and practical, combined with high data availability
Ability to be interlinked with other metrics from other indicators	Ecologically connected to several other indicators
Reporting structure	Useful to many different managers and researchers, also stand alone
Operationalization ability (if included)	Needs reporting in relation to fisheries, temperature, lake levels, & bloom impacts

Appendix D: Complete Metric Scoring and Weighting from Indicator Leads

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 1: Long-term water level variability

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 2: Timing of Seasonal Min Water Level

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			

	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 3: Timing of Seasonal Max Water Level

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals,	Some	0.5			

	criteria	what				
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 4: Magnitude of seasonal rise

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 5: Magnitude of seasonal decline

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Seasonal and Long-term Fluctuations in Great Lakes Water Levels

Metric 6: Lake to Lake water level difference

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	1	1

Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.75	1	0.75
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1	1	1
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	0.5	0.83	1	0.8
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			15	6.42	7	6.42

Water Temperature

Metric 1: Annual summer (July-September) surface average temperature for each lake

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	1	1	2	2	1
Rigorously monitored to report statistically meaningful results for	Entire basin	0.5	0.5	1	0.5	0.75
	Individual lakes	0.5				
	Subunits of lakes	0.5				
	Collection locations	0.5				
Regularly monitored	Is metric regularly monitored	1	0.75	1	0.75	1
	What is the cycle of monitoring?	0.5				
Length of monitoring record	What is the period of record?	0	0.5	3	1.5	1
	Any major gaps in record?	1				
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	1	1	1	1	0.83
	Calibrated within and across Collection Methods	1				

	Has established endpoints, goals, criteria	1				
Owner and cost	Metric has "owner(s)" (yes/no)	1	1	1	1	1
	Estimated cost	1				
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	1	1	1	1	0.8
	Linkage / integrity between biological, chemical, physical	1				
	Utility of collected information	1				
Total			13.5	5.75	10	7.75

Water Temperature

Metric 2: Lake water thermal stratification date

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1	2	2
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	0.5	0.5	1	0.5
	Individual lakes	Yes	0.5			
	Subunits of lakes	No	0.5			
	Collection locations	Yes	0.5			
Regularly monitored	Is metric regularly monitored	Yes	1	0.75	2	1.5
	What is the cycle of monitoring?	Yes	0.5			
Length of monitoring record	What is the period of record?	Long	0	0.5	2	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.67	1	0.67
	Calibrated within and across Collection Methods	Yes	0.5			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	1	1	1	1
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			6.42	**12.5**	**5.42**	**10**

Water Temperature

Metric 3: Fall lake water turnover date

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.00	2.00	2.00	1.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	0.50	1.00	0.50	0.50
	Individual lakes	Yes	1			
	Subunits of lakes	No	0			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	0.75	2.00	1.50	0.75
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	0.25	2.00	0.50	0.25
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	0.67	1.00	0.67	0.67
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Some what	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00	1.00	1.00
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Some what	1.00	1.00	1.00	1.00
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total			6.42	**5.17**	**10.00**	**7.17**

Water Temperature

Metric 4: Maximum and average ice concentrations

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive	Is there comprehensive coverage of	Yes	1.00	1.00	1.00	1.00

data across basin	data for this metric?					
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1.00	0.88	1.00	0.88
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Some what	0.50			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	2.00	2.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	1.00	2.00	2.00
	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	1.00	1.00	1.00
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Yes	1.00			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00	1.00	1.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	1.00	2.00	2.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total			**16.50**	**6.88**	**10.00**	**9.88**

Nutrients-P Loads and In-lake Concentrations

Metric 1: TP Loads from major tributaries

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.00	1.00		0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1.00	1.00	2.00	2.00
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Some what	0.50	0.75	2.00	1.50
	What is the cycle of monitoring?	Yes	1.00			
Length of	What is the period of record?	Long	1.00	0.75	3.00	2.25

monitoring record	Any major gaps in record?	Some what	0.50			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.67		0.00
	Calibrated within and across Collection Methods	Some what	0.50			
	Has established endpoints, goals, criteria	Some what	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Some what	0.50	0.75		0.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	0.83	3.00	2.50
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Some what	0.50			
Total		15		**14.00**	**5.75**	**10.00**

Nutrients-P Loads and In-lake Concentrations

Metric 2: DRP Loads from major tributaries

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0	0		0
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0	0.375		0
	Individual lakes	Some what	0.5			
	Subunits of lakes	Some what	0.5			
	Collection locations	Some what	0.5			
Regularly monitored	Is metric regularly monitored	Some what	0.5	0.75		0
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	0.75		0
	Any major gaps in record?	Some what	0.5			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Some what	0.5	0.5		0
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	No	0			
Owner and cost	Metric has "owner(s)" (yes/no)	Some what	0.5	0.5		0
	Estimated cost	Some what	0.5			
Interpretable,	Metric can produce data on trends	Yes	1	0.67		0

interconnected, and useful	and/or state					
	Linkage / integrity between biological, chemical, physical	Some what	0.5			
	Utility of collected information	Some what	0.5			
Total				**9**	**3.54**	**0**

Nutrients-P Loads and In-lake Concentrations

Metric 3: Total Phosphorus (TP) concentration in lakes

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.00	1.00	3.00	3.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1.00	1.00	2.00	2.00
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00		0.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	1.00	3.00	3.00
	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.83	2.00	1.67
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00		0.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	1.00		0.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total				**16.50**	**6.83**	**10.00**

Nutrients-P Loads and In-lake Concentrations

Metric 4: DRP concentration in lakes

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Somewhat	0.50	0.50		0.00
Rigorously monitored to report statistically meaningful results for	Entire basin			0.67		0.00
	Individual lakes	Somewhat	0.50			
	Subunits of lakes	Somewhat	0.50			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Somewhat	0.50	0.75		0.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	0.75		0.00
	Any major gaps in record?	Somewhat	0.50			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.83		0.00
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00		0.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	No	0.00	0.00		0.00
	Linkage / integrity between biological, chemical, physical	No	0.00			
	Utility of collected information	No	0.00			
Total				**10.00**	**4.50**	**0.00**

PBTs in Biota

Metric 1 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes whole fish

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.00	1.00	1.00	1.00
Rigorously	Entire basin	Yes	1.00	1.00	2.00	2.00

monitored to report statistically meaningful results for	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	1.00	1.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	1.00	1.00	1.00
	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.83	1.00	0.83
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00	1.00	1.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Somewhat	0.50	0.83	3.00	2.50
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total				**16.00**	**6.67**	**10.00**

PBTs in Biota

Metric 2 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes herring gull eggs

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1	1.00	1.00	1.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1	0.88	2.00	1.75
	Individual lakes	Yes	1			
	Subunits of lakes	Somewhat	0.5			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Yes	1	1.00	1.00	1.00
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1.00	1.00	1.00
	Any major gaps in record?	No	1			

Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	0.83	1.00	0.83
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Somewhat	0.5			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1.00	1.00	1.00
	Estimated cost	Yes	1			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Somewhat	0.5	0.83	3.00	2.50
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total				**15.5**	**6.54**	**10.00**

PBTs in Biota

Metric 3 - Indicator measures persistent, bioaccumulating and toxic substances in Great Lakes bald eagles

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Somewhat	0.5	0.5	1	0.5
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0	0.5	2	1
	Individual lakes	Somewhat	0.5			
	Subunits of lakes	Somewhat	0.5			
	Collection locations	Yes	1			
Regularly monitored	Is metric regularly monitored	Somewhat	0.5	0.75	1	0.75
	What is the cycle of monitoring?	Yes	1			
Length of monitoring record	What is the period of record?	Long	1	1	1	1
	Any major gaps in record?	No	1			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1	1	1	1
	Calibrated within and across Collection Methods	Yes	1			
	Has established endpoints, goals, criteria	Yes	1			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1	1	1	1
	Estimated cost	Yes	1			
Interpretable,	Metric can produce data on	Yes	1	1	3	3

interconnected, and useful	trends and/or state					
	Linkage / integrity between biological, chemical, physical	Yes	1			
	Utility of collected information	Yes	1			
Total				**14**	**5.75**	**10**

Harmful and Nuisance Algae

Metric 1 - Metric measures frequency and magnitude of harmful algae blooms

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	2.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.00	0.00	1.00	0.00
	Individual lakes	No	0.00			
	Subunits of lakes	No	0.00			
	Collection locations	No	0.00			
Regularly monitored	Is metric regularly monitored	No	0.00	0.00	1.00	0.00
	What is the cycle of monitoring?	No	0.00			
Length of monitoring record	What is the period of record?	Short	0.50	0.25	1.00	0.25
	Any major gaps in record?	Yes	0.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	No	0.00	0.33	1.00	0.33
	Calibrated within and across Collection Methods	No	0.00			
	Has established endpoints, goals, criteria	Yes	1.00			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	1.00	1.00	1.00
	Estimated cost	Yes	1.00			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	No	0.00	0.33	3.00	1.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	No	0.00			
Total				**4.50**	**1.92**	**10.00**

Harmful and Nuisance Algae

Metric 2 - Metric measures frequency and magnitude of nuisance algae blooms

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.0	1.0	2.0	2.0
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.0	0.5	2.0	1.0
	Individual lakes	Yes	1.0			
	Subunits of lakes	Yes	1.0			
	Collection locations	No	0.0			
Regularly monitored	Is metric regularly monitored	Some what	0.5	0.5	1.0	0.5
	What is the cycle of monitoring?	Some what	0.5			
Length of monitoring record	What is the period of record?	Long	1.0	0.8	1.0	0.8
	Any major gaps in record?	Some what	0.5			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	No	0.0	0.7	1.0	0.7
	Calibrated within and across Collection Methods	Yes	1.0			
	Has established endpoints, goals, criteria	Yes	1.0			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.0	0.8	1.0	0.8
	Estimated cost	Some what	0.5			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.0	0.8	2.0	1.7
	Linkage / integrity between biological, chemical, physical	Yes	1.0			
	Utility of collected information	Some what	0.5			
Total			11.5	5.0	10.0	7.3

Harmful and Nuisance Algae

Metric 3 - Indicator measures frequency and magnitude of harmful and nuisance algae blooms

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	2.00	0.00
Rigorously	Entire basin	No	0.00	0.13	1.00	0.13

monitored to report statistically meaningful results for	Individual lakes	No	0.00			
	Subunits of lakes	Some what	0.50			
	Collection locations	No	0.00			
Regularly monitored	Is metric regularly monitored	No	0.00	0.25	1.00	0.25
	What is the cycle of monitoring?	Some what	0.50			
Length of monitoring record	What is the period of record?	Short	0.50	0.25	1.00	0.25
	Any major gaps in record?	Yes	0.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	No	0.00	0.17	2.00	0.33
	Calibrated within and across Collection Methods	No	0.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	0.75	1.00	0.75
	Estimated cost	Some what	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	No	0.00	0.17	2.00	0.33
	Linkage / integrity between biological, chemical, physical	No	0.00			
	Utility of collected information	Some what	0.50			
Total			**4.00**	**1.71**	**10.00**	**2.04**

Fish Species of Interest

Metric 1 - Metric measures status and trends in population abundance of cold water species and includes lake trout and lake whitefish

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Yes	1.00	1.00	1.00	1.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1.00	1.00	1.00	1.00
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	3.00	3.00
	What is the cycle of monitoring?	Yes	1.00			
Length of	What is the period of record?	Long	1.00	1.00	1.00	1.00

monitoring record	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.83	2.00	1.67
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Some what	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Some what	0.50	0.50	1.00	0.50
	Estimated cost	Some what	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	0.83	1.00	0.83
	Linkage / integrity between biological, chemical, physical	Some what	0.50			
	Utility of collected information	Yes	1.00			
Total			**15.00**	**6.17**	**10.00**	**9.00**

Fish Species of Interest

Metric 2 - Metric measures status and trends in recruitment of the cold water species, lake trout and lake whitefish

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Somewhat	0.50	0.50	1.00	0.50
Rigorously monitored to report statistically meaningful results for	Entire basin	Yes	1.00	1.00	1.00	1.00
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	3.00	3.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	1.00	1.00	1.00
	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Yes	1.00	0.83	2.00	1.67
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Somewhat	0.50	0.50	1.00	0.50
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	0.83	1.00	0.83
	Linkage / integrity between	Somewhat	0.50			

	biological, chemical, physical					
	Utility of collected information	Yes	1.00			
Total			**14.50**	**5.67**	**10.00**	**8.50**

Fish Species of Interest

Metric 3 - Metric measures status and trends in population abundance of cool water species and includes walleye

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	1.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.00	0.63	1.00	0.63
	Individual lakes	Somewhat	0.50			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	3.00	3.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Long	1.00	1.00	1.00	1.00
	Any major gaps in record?	No	1.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Somewhat	0.50	0.67	2.00	1.33
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Somewhat	0.50	0.50	1.00	0.50
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	1.00	1.00	1.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total			**12.50**	**4.79**	**10.00**	**7.46**

Fish Species of Interest

Metric 4 - Metric measures status and trends in recruitment of the cool water walleye

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	1.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	Somewhat	0.50	0.75	1.00	0.75
	Individual lakes	Somewhat	0.50			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			
Regularly monitored	Is metric regularly monitored	Yes	1.00	1.00	3.00	3.00
	What is the cycle of monitoring?	Yes	1.00			
Length of monitoring record	What is the period of record?	Medium	0.00	0.25	1.00	0.25
	Any major gaps in record?	Somewhat	0.50			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Somewhat	0.50	0.67	2.00	1.33
	Calibrated within and across Collection Methods	Yes	1.00			
	Has established endpoints, goals, criteria	Somewhat	0.50			
Owner and cost	Metric has "owner(s)" (yes/no)	Somewhat	0.50	0.50	1.00	0.50
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	1.00	1.00	1.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total			**11.50**	**4.17**	**10.00**	**6.83**

Fish Species of Interest

Metric 5 - Metric measures status and trends in population abundance for lake sturgeon

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	Somewhat	0.50	0.50	1.00	0.50
Rigorously monitored to report statistically meaningful results for	Entire basin	Somewhat	0.50	0.88	1.00	0.88
	Individual lakes	Yes	1.00			
	Subunits of lakes	Yes	1.00			
	Collection locations	Yes	1.00			

Regularly monitored	Is metric regularly monitored	Somewhat	0.50	0.50	3.00	1.50
	What is the cycle of monitoring?	Somewhat	0.50			
Length of monitoring record	What is the period of record?	Medium	0.00	0.25	1.00	0.25
	Any major gaps in record?	Somewhat	0.50			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Somewhat	0.50	0.33	2.00	0.67
	Calibrated within and across Collection Methods	Somewhat	0.50			
	Has established endpoints, goals, criteria	No	0.00			
Owner and cost	Metric has "owner(s)" (yes/no)	Yes	1.00	0.75	1.00	0.75
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Yes	1.00	1.00	1.00	1.00
	Linkage / integrity between biological, chemical, physical	Yes	1.00			
	Utility of collected information	Yes	1.00			
Total			**11.00**	**4.21**	**10.00**	**5.54**

Fish Species of Interest

Metric 6 - Metric measures status and trends in recruitment of lake sturgeon

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	1.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.00	0.00	1.00	0.00
	Individual lakes	No	0.00			
	Subunits of lakes	No	0.00			
	Collection locations	No	0.00			
Regularly monitored	Is metric regularly monitored	No	0.00	0.25	3.00	0.75
	What is the cycle of monitoring?	Somewhat	0.50			
Length of monitoring record	What is the period of record?	Short	0.50	0.25	1.00	0.25
	Any major gaps in record?	Yes	0.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	Somewhat	0.50	0.17	2.00	0.33
	Calibrated within and across Collection Methods	No	0.00			
	Has established endpoints,	No	0.00			

	goals, criteria					
Owner and cost	Metric has "owner(s)" (yes/no)	Somewhat	0.50	0.50	1.00	0.50
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Somewhat	0.50	0.67	1.00	0.67
	Linkage / integrity between biological, chemical, physical	Somewhat	0.50			
	Utility of collected information	Yes	1.00			
Total			**4.50**	**1.83**	**10.00**	**2.50**

Fish Species of Interest

Metric 7 - Metric measures status and trends in population abundance for warm water species, including northern pike, and smallmouth bass/largemouth bass

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	1.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.00	0.25	1.00	0.25
	Individual lakes	No	0.00			
	Subunits of lakes	Somewhat	0.50			
	Collection locations	Somewhat	0.50			
Regularly monitored	Is metric regularly monitored	No	0.00	0.25	3.00	0.75
	What is the cycle of monitoring?	Somewhat	0.50			
Length of monitoring record	What is the period of record?	Medium	0.00	0.00	1.00	0.00
	Any major gaps in record?	Yes	0.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	No	0.00	0.00	2.00	0.00
	Calibrated within and across Collection Methods	No	0.00			
	Has established endpoints, goals, criteria	No	0.00			
Owner and cost	Metric has "owner(s)" (yes/no)	No	0.00	0.25	1.00	0.25
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	Somewhat	0.50	0.83	1.00	0.83
	Linkage / integrity between	Yes	1.00			

	biological, chemical, physical					
	Utility of collected information	Yes	1.00			
Total			**4.50**	**1.58**	**10.00**	**2.08**

Fish Species of Interest

Metric 8 - Metric measures status and trends in recruitment of northern pike and smallmouth bass/largemouth bass

Metric: Category	Filter	Answer	Score	Raw Category Average Score	Category Weighting Modifier	Weighted Category Score
Comprehensive data across basin	Is there comprehensive coverage of data for this metric?	No	0.00	0.00	1.00	0.00
Rigorously monitored to report statistically meaningful results for	Entire basin	No	0.00	0.13	1.00	0.13
	Individual lakes	No	0.00			
	Subunits of lakes	No	0.00			
	Collection locations	Somewhat	0.50			
Regularly monitored	Is metric regularly monitored	Somewhat	0.50	0.50	3.00	1.50
	What is the cycle of monitoring?	Somewhat	0.50			
Length of monitoring record	What is the period of record?	Medium	0.00	0.00	1.00	0.00
	Any major gaps in record?	Yes	0.00			
Natural variation, calibration and endpoints	Calibrated to account for natural variation across space and time	No	0.00	0.00	2.00	0.00
	Calibrated within and across Collection Methods	No	0.00			
	Has established endpoints, goals, criteria	No	0.00			
Owner and cost	Metric has "owner(s)" (yes/no)	No	0.00	0.25	1.00	0.25
	Estimated cost	Somewhat	0.50			
Interpretable, interconnected, and useful	Metric can produce data on trends and/or state	No	0.00	0.50	1.00	0.50
	Linkage / integrity between biological, chemical, physical	Somewhat	0.50			
	Utility of collected information	Yes	1.00			
Total			**3.50**	**1.38**	**10.00**	**2.38**

Appendix E: Supplementary Report – Aquatic Invasive Species and Chemicals of Mutual Concern Indicators

The Communicability of Aquatic Invasive Species and Chemicals of Mutual Concern Indicators

A Supplemental Report to the "An Assessment of the Communicability of the IJC Ecosystem Indicators & Metrics" Report

Submitted by the Aquatic Invasive Species and Chemicals of Mutual Concern Indicators Work Group of the Science Advisory Board

June 06, 2016

Background and Methods

In 2014 the Science Advisory Board's Science Priority Committee (SPC) initiated a project to identify a smaller set of indicators from the existing 16 ecosystem indicators identified by the International Joint Commission for the purpose of public communications. The results of that project have been reported in the main report[9], and resulted in the selection of six indicators, and for each indicator a single metric.

The Commission requested that the SPC add two more indicators– aquatic invasive species (AIS) and chemicals of mutual concern in water (CMC). A work group of the SAB was established in March, 2016 to apply the SPC's metric-level assessment process to identify best metrics for these two indicators. This supplemental report summarizes the results of this analysis.

Using information on data availability gathered and summarized by the contractor and experts' knowledge, the work group scored the metrics of AIS and CMC based on a set of filters that were used by the SPC for the six indicators described in the main report (work was largely done through two subgroups covering each indicator – see below). Filter scores were summed for each metric within the indicator to develop a raw score for each metric. Work group members

[9] Science Priority Committee, 2016. An Assessment of the communicability of the International Joint Commission ecosystem indicators and metrics. Prepared for the International Joint Commission. 61 pages + appendices.

then applied a weight (1-3) to develop the weighted score for each metric. These weights were applied based on how relevant the leads felt the filter was to the ability to communicate the metric. The weighted score of each metric was then used to rank all metrics within the indicator. The experts chosen for each of the indicators are indicated in the table below.

Indicator experts for the metric scoring and weighting process

Indicator	**Experts**
Aquatic Invasive Species	Debbie Lee, Gavin Christie, Lindsay Chadderton
Chemicals of Mutual Concern in Water	Michael Murray, Michael Twiss, Norm Grannemann, Chris Winslow

Results and Discussion

Aquatic Invasive Species

The purpose of the metric-level prioritization is to provide objective feedback to the IJC to help inform investments into monitoring programs for one or more of the seven metrics associated with the aquatic invasive species communication indicators (Table 1).

Among the seven metrics of this indicator, sea lamprey abundance was ranked the highest (Tables 1 and 2). Data for this metric was considered to be high quality as it has comprehensive and evenly distributed data across the basin and is regularly monitored. Although there are few gaps in the United States sea lamprey record, there are some significant gaps in the monitoring record in the Canadian record that has led to a lower score for that filter.

Sea lamprey abundance metric was also ranked highly in practicality. The metric has established endpoints, goals and criteria, and has a funded owner into the future. The metric can stand alone to tell a compelling, integrated story. Furthermore, the information can be used by external programs such as the Great Lakes Fishery Commission’s Sea Lamprey Control program.

The rate of invasion and ruffe relative abundance metrics were rated the second highest. The rate of invasion metric has comprehensive coverage of data across the basin, and can produce data on trend and state integrity between biological, chemical, and physical utility of collected information. The rate of invasion metric is very weak in the filter of rigorously monitored to report statistically meaningful results for the entire Great Lakes Basin. The ruffe relative abundance metric also has comprehensive coverage of data across the basin and is regularly monitored. The ruffe relative abundance metric is very weak in the filter of establishing a desired endpoint or range of conditions.

Overall, our effort identified that actions on improving the communicability of all the metrics of the aquatic invasive species indicator are needed, although sea lamprey abundance has relatively better communicability. We recommend that future efforts should focus on rate of invasion as a top priority as it serves as a general metric to assess progress against programs and policies designed to keep new invaders out or from expanding between lakes. This recommendation is based on that the other metrics are largely a measure of control programs on aquatic invasive species that are already in the lakes or a measure of changes in the ecosystem that lead to self-regulation of those invasive populations.

Table 2 below shows the summarized filter scoring results and raking for aquatic invasive species metrics.

Table 21 Expert lead's filter scoring of each metric within the Aquatic Invasive Species indicator

Metric: Category	Filter	Rate of Invasion	Sea Lamprey Abundance	Invasive Zooplankton Biomass	Asian Carp	Dreissenid Mussel Abundance	Round Goby Relative Abundance	Ruffe Relative Abundance	Average Within Filter Across Metrics
Data Across Basin	Is there comprehensive coverage of data for this metric?	1.0	1.0	0.5	0.5	0.5	0.5	1.0	0.7
Rigorously Monitored to Report Statistically Meaningful Results for	Entire basin Individual lakes Subunits of lakes Collection locations	0.4	0.8	0.4	0.5	0.5	0.5	0.5	0.5
Regularly Monitored	Is metric regularly monitored What is the cycle of monitoring?	0.8	1.0	0.8	0.5	0.5	0.8	1.0	0.8
Length of Monitoring Record	What is the period of record? Any major gaps in record?	0.5	0.5	0.8	0	0.5	0.5	0.5	0.5
Natural Variation, Calibration and Endpoints	Calibrated to account for natural variation across space and time Calibrated within and across collection methods Has established endpoints, goals,	0.7	1.0	0.3	0.5	0.3	0.2	0.3	0.5

	criteria								
Owner and Cost	Metric has "owner(s)" (yes/no) Estimated cost	0.8	1.0	1.0	1.0	0.5	1.0	0.8	0.9
Interpretable Inter-connected, and Useful	Metric can produce data on trends and/or state Linkage / Integrity between biological, chemical, physical Utility of collected information	1.0	1.0	0.5	0.8	0.3	0.5	0.8	0.7
	Average among filter within metric	0.7	0.9	0.6	0.6	0.5	0.6	0.7	0.6

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

Table 22 Top ranked metrics within Aquatic Invasive Species indicator

Metric	**Raw Score**	**Weighted Score**	**Rank**
Sea Lamprey Abundance	6.25	9.25	1
Rate of Invasion	5.04	7.79	2
Ruffe Relative Abundance	4.92	7.75	3
Invasive Zooplankton Biomass	4.21	5.96	4
Asian Carp	3.83	5.67	5
Round Goby Relative Abundance	3.92	5.67	6
Dreissenid Mussel Abundance	3.67	5.5	7

Chemicals of Mutual Concern in Water

The chemicals of mutual concern in water indicator initially did not have any specific associated metrics. This was largely due to the fact that during the time period in which this assessment was carried out (spring 2016), the Parties had yet to formally designate individual CMCs, though candidate CMCs had been identified. Consistent with this situation, the IJC indicator data accessibility analysis (Roth et al., 2016) conducted in support of this overall effort assessed toxic chemicals generally (rather than individual chemicals) in offshore waters. In spite of the lack of focus on individual chemicals, the value of going through the process for this indicator was recognized, including to identify strengths and potential weaknesses (e.g. data deficiencies) and for comparing the communicability of the metric in relation to other indicators. The resulting scores for this exercise are compiled in Table 3.

In this assessment data from the Canadian side are generally considered to be comprehensive for a number of contaminants, including legacy contaminants, and to some extent chemicals of emerging concern. Data collection dates back to the mid-1980s, providing long-term coverage. However, data are lacking from the United States due to the termination of the Environmental Protection Agency's chemicals in water monitoring program approximately seven years ago. This data gap mainly affects Lake Michigan as Environment and Climate Change Canada (ECCC) continues to monitor the other four lakes for contaminants; the Lake Michigan data gap is the reason for low scores in the "comprehensive data across basin" and "rigorously monitored" categories. Further adding to data quality issues, the sampling and processing protocol done by Canada changed in 2004 and it is not clear whether any comparison of techniques was done. Regarding endpoints and goals, one question is whether the governments will develop formal water quality guidelines for designated CMCs (for chemicals currently without them).

The filter categories of "interpretable, interconnected, and useful" were scored the highest in communicability. In particular, it is recognized that a CMCs in water indicator ties closely to the PBTs (persistent, bioaccumulative, toxic chemicals) in Biota indicator (addressed in the main indicator report), for those CMCs that are also PBT chemicals. In addition, CMCs in water tie in directly to human health concerns (e.g. via potential drinking water exposures (IJC 2014b)).

Related value of this indicator includes the potential for water data to be coupled with biota data in determination of bioaccumulation factors. Trend assessments (which would also be of interest to the public) can be carried out, though issues such as changes in protocols, monitoring gaps, and measurement sensitivity need to be considered in data interpretation. Indeed analytical challenges are commonly seen for multiple toxic chemicals monitored in Great Lakes waters (Environment Canada and U.S. EPA, 2014).

Tables 3 and 4 below show the filter scoring results for the CMC indicator's single metric, and raw versus weighted score, respectively.

As the subgroup work was being finalized in late spring, the Parties announced the formal designation of CMCs. Those chemicals (or chemical groups) are:

- Hexabromocyclododecane (HBCD)
- Long-Chain Perfluorinated carboxylic acids (LC-PFCAs)
- Mercury
- Perfluorooctanoic acid (PFOA)
- Perfluorooctane sulfonate (PFOS)
- Polybrominated Diphenyl Ethers (PBDEs)
- Polychlorinated Biphenyls (PCBs)
- Short-Chain Chlorinated Paraffins (SCCPs) (Canada and U.S., 2016)

Accordingly, the work group recommends that a quantitative ranking of those CMCs be completed using the filters described in the main indicator report, an effort that could identify additional potential CMC metrics, that among other things can help highlight specific deficiencies and knowledge gaps to improve communicability, and inform the Parties as to progress in addressing those CMCs.

Prior to the announcement of the Parties of the formal designated CMCs, the work group decided to qualitatively consider candidate CMCs (announced in 2014) from the perspective of their communicability.[10] Based on best professional judgement, the work group recommends

[10] Candidate CMCs were Bisphenol A, chlorinated paraffins (alkanes) (including short, medium and long chain), flame retardants (Polybrominated diphenyl ethers (PBDEs) and Hexabromocyclododecane (HBCD)), mercury, nonyphenol (NP) and its ethoxylates (NPEs, perfluorinated compounds (PFOA, PFCA, PFOS), and Polychlorinated Biphenyls (PCBs) (Canada and U.S., 2015).

that of the seven proposed CMCs/groups, mercury[11] was well suited for communicating with the public because:

i. mercury is a contaminant that already has considerable awareness among the public e.g., mercury is responsible for a majority of fish consumption advisories in the Great Lakes (Environment Canada and EPA, 2014).
ii. adequate concentration data exist for mercury in sediment, water, biota and fish.
iii. mercury is persistent in the environment.
iv. mercury emissions reduction has been a major focus of binational programs for several decades (and in part due to such actions, out-of-basin sources represent the majority of atmospherically-deposited mercury to the lakes, though one recent assessment indicated the U.S. is still the most important single contributor (IJC, 2015)).
v. mercury can be used to communicate the complexity of chemical cycling in the Great Lakes e.g., concentrations in water are generally going down, but concentrations in some fish species are going up.

The work group felt that both total mercury and methylmercury should be considered.

The work group also recommends that a chemical that originates from local or regional sources and is not a persistent, bioaccumulative, toxic substance should be added as a metric to the CMC indicator. The work group identified atrazine (a herbicide commonly used to control pre- and post-emergent broadleaf weeds throughout the agricultural portion of the Great Lakes basin) as a suitable metric given it is a commonly measured pesticide in surface and groundwater that originates from within the basin, and is increasing in concentrations in the Great Lakes (Environment Canada and EPA, 2014). Further, atrazine exhibits relatively low persistence and has low bioaccumulation potential (so would not be captured in the PBT in Biota indicator). Atrazine exposure has been linked to adverse developmental outcomes in amphibians and reproductive effects in humans, and was included as one of the measures recommended by the Health Professionals Advisory Board in support of the chemical integrity of source water indicator (IJC, 2014b).

[11] Note that mercury is also now included as a formally designated CMC.

The work group notes that atrazine was not included among the newly designated CMCs (though it could potentially be designated in the future). However, given the interest in identifying one or more chemicals that are not formally PBT chemicals, we note that all of the newly designated chemicals/groups are either formally PBT chemicals or otherwise display at least moderate potential for persistence, bioaccumulation, and toxicity, so again, can potentially be addressed through a refined PBTs in Biota indicator.

Given time limitations, the work group was not able to do a systematic assessment of the newly designated CMCs with all filters utilized in this process. However, as noted in an earlier recommendation such an effort should be undertaken. At the same time, we also reiterate that the work group sees value in ensuring that CMCs in water metrics not be focused exclusively on PBT chemicals that may potentially be captured within the PBTs in Biota indicator as well.

Table 23 Expert lead's filter scoring of each metric within the Chemicals of Mutual Concern indicator

Metric: Category	Filter	CMC in Water	Average Within Filter Across Metrics
Comprehensive Data Across Basin	Is there comprehensive coverage of data for this metric?	0.5	0.5
Rigorously Monitored to Report Statistically Meaningful Results for	Entire basin Individual lakes Subunits of lakes Collection locations	0.5	0.5
Regularly Monitored	Is metric regularly monitored What is the cycle of monitoring?	0.75	0.75
Length of Monitoring Record	What is the period of record? Any major gaps in record?	0.75	0.75
Natural Variation, Calibration and Endpoints	Calibrated to account for natural variation Across space and time Calibrated within and across collection methods Has established endpoints, Goals, criteria	0.5	0.5
Owner and Cost	Metric has "owner(s)" (yes/no) Estimated cost	0.5	0.5
Interpretable, Interconnected, and Useful	Metric can produce data on trends and/or state Linkage / integrity between biological, chemical, physical Utility of collected information	1	1
	Average among filter within metric	0.64	0.64

Legend	No issues with communicability	Minor issues	Moderate issues	Major issues	Severe issues with communicability

Table 24 Top ranked metrics within Chemicals of Mutual Concern indicator

Metric	Raw Score	Weighted Score
CMC in water	4.5	6.5

References Cited

Canada and U.S., 2015. Public Comment Completed: Canada and the United States Release Draft Binational Summary Reports for Candidate Chemicals of Mutual Concern. Accessed June 3, 2016 at https://binational.net/2015/05/13/cmc-cand-pcspm/.

Canada and U.S., 2016. Canada and the United States Designate the First Set of Chemicals of Mutual Concern. Accessed June 3, 2016 at http://binational.net/2016/05/31/cmcdesig-pcpmdesig/.

Environment Canada and U.S. Environmental Protection Agency, 2014. State of the Great Lakes 2011. 548 pages. Accessed May 30, 2016 at http://binational.net/wp-content/uploads/2014/11/sogl-2011-technical-report-en.pdf.

International Joint Commission, 2015. Atmospheric Deposition of Mercury in the Great Lakes Basin. 17 pages. Accessed May 30, 2016 at http://ijc.org/files/tinymce/uploaded/documents/Atmospheric-Deposition-of-Mercury-in-the-Great-Lakes-Basin-December-2015.pdf.

International Joint Commission, 2014a. Great Lakes Ecosystem Indicator Project Report. A Report of the IJC Priority Assessment of Progress towards Restoring the Great Lakes. 63 pages. Accessed May 30, 2016 at http://www.ijc.org/files/publications/Ecosystem%20Indicators%20-Final.pdf.

International Joint Commission, 2014b. Recommended Human Health Indicators for Assessment of Progress on the Great Lakes Water Quality Agreement. Prepared by the Health Professionals Advisory Board. 48 pages + appendices. Accessed May 30, 3016 at http://ijc.org/files/tinymce/uploaded/HPAB/Recommended-Human-Health_Indicators-June2014.pdf.

Roth, B.M., Riseng, C.M., Sparks-Jackson, B.L., Fetzer, W.W. and Infante, D.R., 2016. Great Lakes Indicator Data Accessibility and Data Gaps Analysis for Assessing Progress Towards Achieving the GLWQA Objectives. Contractor report prepared for the IJC Science Advisory Board (Research Coordination Committee). 111 pages + appendices