Assessment of Progress Made Towards Restoring and Maintaining Great Lakes Water Quality Since 1987

16th Biennial Report on Great Lakes Water Quality

International Joint Commission
of Canada and the United States of America

Assessment of Progress Made Towards Restoring and Maintaining Great Lakes Water Quality Since 1987

Sixteenth Biennial Report on Great Lakes Water Quality

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Dear Friends of the Great Lakes:

The International Joint Commission (IJC) is pleased to transmit our Sixteenth Biennial Report on Great Lakes Water Quality, concluding our responsibilities under the 1978 Canada-United States Great Lakes Water Quality Agreement, as amended by the 1987 Protocol. The goal of this report is to present a scientifically sound yet broadly accessible picture of how the health of the Great Lakes has changed over the 25 years since the Agreement was last revised. The data presented show significant achievements; however, the evidence equally demands sustained investment and action to protect and restore the Great Lakes for today, tomorrow and for generations to come.

In order to address the frequently heard question: "Are the Great Lakes getting healthier?" we made a concerted effort to locate data and work with experts from both sides of the border. Recognizing that there are no simple answers, authors of this report selected 14 well-documented indicators of chemical, physical and biological integrity, and two indicators of performance. Only indicators with data that spanned all or most of the 25-year period were included in this report and most data were from the State of the Lakes Ecosystem Conference (SOLEC).

The seven indicators of chemical integrity show mostly favorable or stable results since 1987, reflecting the success of policy changes implemented in both countries after the original 1972 Agreement. However, some data also reveal a leveling off or even a reversal of reductions in toxic chemicals and nutrient loadings in the past decade and earlier. For example, recent extreme algal blooms are in part a manifestation of excessive nutrient loadings. Clearly, past policy changes and investments have been effective, and our findings support the need for more comprehensive monitoring of these indicators and scientifically justifiable actions to protect the public.

The five biological indicators reveal mixed results, both among the indicators and over time. For instance, from 1987 to 2006, 34 new non-native species became established in the Great Lakes, causing extensive and costly damage to the ecosystem. However, since 2006 when modifications in ballast water management regulations were implemented, no new invasive species are known to have been introduced through ballast water, though two species were established via other routes. In addition to prevention measures, IJC recommendations include highly coordinated plans for rapid response to any future introductions.

The two physical indicators in the report show rising surface water temperatures and reduced ice cover. Such concerns about global climate change prompted the IJC to support further

inquiry into adaptive management practices which provides a systematic approach to help minimize future damage to Great Lakes dependent communities. The report recognizes that water quality is the focus of the Agreement but draws attention to increasing concerns about water levels and the impacts of declining water levels on water quality.

Finally, two performance indicators reflect how well government programs were meeting objectives regarding restoration of 43 sites of historic contamination identified as Areas of Concern (AOC) under terms of the 1987 Protocol, and beach closings and advisories. Only four AOCs (three in Canada and one in the U.S.) have been remediated to the point of being delisted. Many individual beneficial use impairments (BUI) have been removed at a number of sites that have been partially remediated. Canada made its greatest gains in the early years of this reporting period, while the pace of remediation of the U.S. sites has picked up in recent years because of increased investment and effort under the U.S. Great Lakes Restoration Initiative and the Great Lakes Legacy Act. Beach closings and advisories have remained nearly unchanged over the full length of the reporting period with some year to year fluctuations.

Scientifically sound indicators applied consistently over time are essential to track changes in Great Lakes water quality. Collaboration between the IJC and the governments' own Great Lakes evaluation program, SOLEC, to select a core set of Great Lakes indicators is key among our recommendations. With these indicators in place, efforts could focus on setting goals or targets for each indicator and allocation of adequate resources for monitoring, prevention and remediation. To support this effort, the IJC has created an indicators work group that includes both government and academic scientists and policy experts. This group already has done considerable analysis and will recommend a specific suite of indicators. Another team of experts is identifying a core set of human health indicators. The Commission has greatly appreciated the support received for these initiatives from the governments.

The scope of work presented in this report constitutes a substantial representation of IJC Great Lakes projects. In addition, there are other projects supportive of IJC's assessment work, including:

- development of systems to support better access and more integration of data provided by academic and government sources in both countries;
- collaboration with stakeholders to improve understanding of factors affecting the reoccurrence of extreme algal blooms;
- extensive studies on forces affecting Great Lakes water levels, resulting in better understanding of precipitation, evaporation, historic dredging, control structures and hydropower facilities, ground water discharge and climate change.

Looking forward, the IJC congratulates the governments of Canada and the United States for successfully completing and signing a revised protocol of the Agreement in 2012. In particular, we appreciate that many of our recommendations were included.

We are particularly eager to implement the Agreement's new opportunities for more public engagement, knowing that an informed and committed public is essential for

adequate investment in Great Lakes protection and restoration.

We are very appreciative of the work of many federal, provincial and state experts who have made substantial contributions to the science underpinning this report. Combined with the continuing effort of these dedicated scientists and managers, we hope the findings and recommendations in this report will help both countries achieve the goals that our two nations have set for protecting and restoring the most precious freshwater ecosystem on earth.

Respectfully submitted,

The Commissioners

Authors, Reviewers, Contributors, and Dedication

The International Joint Commission (IJC) prepared this document with the input of numerous experts from Canada and the United States. Scientific experts from multiple government and other organizations in both countries contributed data and interpretation, while IJC staff synthesized the information, provided input from other literature, and developed policy recommendations. This report is a shorter version of a technical report and is intended for a general audience. The accompanying technical report is intended for scientists and is available at www.ijc.org/en_/Great_Lakes_Quality.

An early draft of this report was released to the public on the IJC's website and at the 2011 Great Lakes Water Quality Biennial Meeting in Detroit from October 12-14, 2011. The draft report was revised based on comments received from multiple Great Lakes organizations, members of IJC's Great Lakes advisory boards, Environment Canada and USEPA. The IJC appreciates the comments from its many reviewers which help provide the perspectives of the Great Lakes community. However, any errors or omissions or opinions expressed are the sole responsibility of the IJC. Several IJC staff helped write this report. The lead author of the report was Vic Serveiss and other contributors were Dave Dempsey, Cindy Warwick, Raj Bejankiwar, Antonette Arvai, Joel Weiner, Paul Allen, and Bruce Kirschner.

The IJC would like to dedicate this report to Bruce Kirschner (1952–2012) who worked with the IJC's Great Lakes Regional Office in Windsor for 23 years and contributed to this report. We hope that this report will influence decisions to help protect and restore the Great Lakes and will be a memorial to his contributions.

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INTRODUCTION AND BACKGROUND

The Great Lakes Water Quality Agreement, of 1987 (hereafter referred to as 1987 Agreement), required the IJC to report biennially to the federal, state, and provincial governments concerning progress made towards achieving Agreement objectives and the effectiveness of programs and measures used to pursue objectives. This, the International Joint Commission's (IJC's) 16th Biennial Report, assesses progress by examining changes since 1987. The findings are intended to provide useful information for the implementers of the revised 2012 Agreement. The report also recommends improvements to research, monitoring and reporting that will enhance the reporting on progress by the governments under the 2012 Agreement. This in turn will help the IJC's assessment of progress and the communication of progress to key decision makers and the public. The ultimate goal is to provide advice to the governments to help them achieve the objectives of the 2012 Agreement.

Both the 1987 and 2012 versions of the Agreement require the governments of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes. General objectives relate to keeping the water free from pollutants that are toxic to human, animal or aquatic life, or interfere with beneficial uses. Keeping the Great Lakes healthy is critical to the economic, human and ecological health of the basin. It is the policy of both governments that discharges of toxic substances at dangerous levels be prohibited and that the release of persistent toxic substances be virtually eliminated. Significant pollution of the Great Lakes can expose the 35 million basin residents to serious health problems while imposing recreational restrictions and economic losses. Children are particularly vulnerable to exposures that can cause life-long developmental deficits, and First Nations, tribes and Métis have lifestyles that are especially threatened because of their reliance on Great Lakes fish as a source of food and the waters as fundamental to their cultural values.

Government's Responsibility to Report on Progress

Many of the Annexes in the 1987 Agreement required the governments to report to the Commission biennially on their progress towards achieving objectives of the Agreement. For example, Annexes 14 and 15 on Contaminated Sediment and Atmospheric Toxic

Substances, respectively, required the governments to report biennially on their progress in implementing these Annexes to the Commission. From 1972 to 1987, government officials provided the biennial progress reports while serving as members of a network of specialized subcommittees that were part of the Commission's advisory boards. With the requisite data available, the biennial reports at that time were more effective at assessing progress on objectives. However, the 1987 Agreement changed the protocol, the subcommittees were disassembled, and the responsibility of providing data to the IJC was transferred to the governments.

Since 1987, the Commission has not received assessment of progress reports on each of the annexes, nor are the reported indicators linked to the Agreement's objectives. The governments' State of the Lakes Ecosystem Conference (SOLEC) has reported on various indicators related to the chemical, biological and physical integrity of the waters of the Great Lakes, however, the reported indicators have not been clearly linked to the Agreement's objectives.

The Commission is pleased that the revised 2012 Agreement better clarifies the governments responsibilities. The governments are now responsible for reporting to the public on progress in achieving the objectives of the Agreement through the new Progress Report of the Parties, the State of the Great Lakes Report and the Lakewide Action and Management Plans.

IJC's Responsibility to Report on Progress

The 1987 Agreement required the IJC to report biennially to the federal, state and provincial governments concerning progress made toward achieving objectives and the effectiveness of programs and measures used. This has become a triennial requirement under the 2012 revised Agreement. In both the 1987 and 2012 Agreements, the IJC is also tasked with providing advice and recommendations on many matters related to Great Lakes water quality and achievement of Agreement objectives.

The 1987 Agreement changed the process for the governments to provide data to the IJC upon which the IJC would develop its biennial assessment report. After that change it became a challenge for the IJC to obtain data that clearly related to the general and specific objectives of the 1987 Agreement, as discussed in the preceding section on the government's reporting requirements.

The IJC has drawn attention to this situation in the past. The 13th Biennial Report of Great Lakes Water Quality (IJC 2006a) was devoted to the challenge of accountability, including the need for the Parties to provide data. The report addressed the general issue of accountability and how objectives of the 1987 Agreement needed to be met with performance measures, management actions to achieve the measures and public reports on the status of these achievements.

Due to the challenge of obtaining data, the IJC's recent biennial reports have focused on particular aspects of the Agreement but were not the comprehensive assessments that the

Agreement directs the IJC to undertake. For instance, as discussed, the 13th biennial focused on accountability. The 14th Biennial Report (IJC 2009) addressed wastewater treatment, and provided recommendations for reducing nutrient loadings from this source. The 15th biennial discussed issues related to water quality in the nearshore zone of the Great Lakes.

In this 16th Biennial Report, the IJC re-initiates its comprehensive assessment of progress, more closely envisioned by both versions of the Agreement. Since this is the final report under the 1987 Agreement, the IJC made a concerted effort to obtain information and work with experts from both countries to perform a more rigorous assessment of progress. In particular, the report focuses on changes in the health of the Great Lakes since 1987, basing the bulk of its findings on measurements of 16 distinct indicators of Great Lakes conditions, stressors, or government programs.

This is the IJC's final Biennial Report because under the 2012 Agreement, reports should be issued on a triennial basis. The revised 2012 Agreement improves the reporting responsibilities for both the governments and the IJC. Now that a revised Agreement has been signed by Canada and the United States, the IJC is pleased that the reporting responsibilities have been clarified and that 1) the governments are now responsible for developing progress reports towards objectives of the 2012 Agreement, as opposed to just reporting on progress towards individual Annexes as stipulated under the 1987 Agreement; and 2) the IJC is responsible for continuing to assess progress towards objectives and has the added responsibility for reviewing the government's progress report. This clarification of roles should help ensure development of comprehensive progress reporting by the governments and the IJC's independent binational assessment.

Importance of Great Lakes Indicators

Scientifically sound indicators applied consistently over time are essential to track changes in Great Lakes water quality. The IJC has long advocated using indicators to measure progress toward Agreement objectives and has recommended criteria for selecting them. IJC has recognized that resources are only available to monitor and compile information on a limited set of indicators.

Abundant ecological indicator literature exists beyond the IJC reports. The US Environmental Protection Agency (USEPA) 2011 report *Aquatic Ecosystems, Water Quality, and Global Change: Challenges of Conducting Multi-Stressor Global Change Vulnerability Assessments* identified a list of 23 studies from government, academia and consultants used by USEPA as core literature for selecting indicators. Indicators have been defined and used to report generally on the condition of the overall environment or for more specific applications such as providing evidence for climate change.

The IJC currently holds the view that there should be a set of 10-30 core indicators that should relate to the objectives of the 2012 Agreement and track changes over time. Most of these indicators should have historical data, some should address nearshore and open

water conditions, a few of them should reflect human health and at least one should consider atmospheric deposition. The IJC has tasked its advisory boards to provide a specific list of indicators based on this guidance. SOLEC representatives from Environment Canada (EC) and USEPA are consulting with the advisory boards in this process and this group will provide recommendations to the IJC. Based on those recommendations, IJC will issue more specific advice to the governments.

Having core indicators for which monitoring and prevention/remediation actions will be provided are essential. Such core indicators provide the public and policy makers with scientifically sound information to make better monitoring, restoration, and prevention decisions.

While the indicators must be scientifically based, take-home messages about conditions and trends must also be accessible for the general public and readily understandable. Inevitably, any limited set of indicators will not measure all the parameters desired to address progress under the Agreement, but they should be sufficient to tell the story of progress and of problems in the ecosystem.

The IJC recognizes that the science behind selecting and defining the state of the lakes is important for assessing progress and that indicator selection and interpretation will continuously evolve. However, progress reports would never be written if everyone waited for the perfect set of indicators. Assessments of progress must proceed using a manageable number of the best available indicators and data, so that governments and the public can continuously take steps to protect and restore the Great Lakes.

The IJC recommends that the governments develop their required progress reports related to the objectives of the Agreement, using a set of core indicators. The IJC also strongly recommends that the governments ensure the continued monitoring, assessment and reporting of status and trends for these indicators. Targets, goals or standards should be developed for each of the core indicators and resources should be provided for protection and restoration actions to achieve the goals.

Additional indicators, beyond the core set, can be valuable for research and resource management purposes. Provided resources are available for addressing the needs of the core indicators, resources could be allocated for monitoring data for additional indicators beyond the core set and these too should have targets, and governments should undertake the necessary actions to achieve them.

Relationship with the State of the Lakes Ecosystem Conference

One role of the IJC is to provide the governments of Canada and the United States with independent, binational science-based advice. To meet its responsibilities, the IJC needs to work in close collaboration with several government departments and agencies in both countries. In particular, the assessment of progress in achieving the goals of the Agreement requires a close exchange of information between the IJC and the agencies involved with creating the SOLEC reports.

SOLEC was established under the 1987 Agreement. Since 1994, the US Environmental Protection Agency and Environment Canada have hosted conferences every two years on behalf of the two countries. Under the 2012 Agreement, the conferences will be held every three years. The conferences report on the state of the Great Lakes ecosystem and the major factors impacting it and provide a forum for exchange of information among Great Lakes decision makers, scientists and stakeholders. Tapping into the resources of multiple government agencies and other organizations, SOLEC reports assess the state of the Great Lakes ecosystem based on accepted indicators and help improve decision-making and resource management.

The SOLEC indicator reports can provide much of the information required by the IJC to write its periodic assessment of progress reports. The SOLEC reports by design are not intended to have the same purpose as IJC's own independent assessment of progress report. The IJC has a complementary but different role to play.

While the SOLEC reports are broad in scope and useful in their content, they would be even more helpful if organized in a manner that clearly linked to the Agreement's objectives. More attention to consistent and historical trend analysis would enhance their value. Because the SOLEC report is web-based, it could be better organized to meet the diverse information needs of various users. These changes would make the SOLEC reports more useful for resource managers while also facilitating the IJC's progress report. SOLEC reports could be organized in such a manner to link its indicator reports to 2012 Agreement objectives to facilitate development of the IJC's assessment of progress report. Also, indicator reports could be sorted temporally, spatially, or by topic to better meet particular needs of resource managers. For instance, the system should allow a user to quickly find those indicator reports with data from 2000 to present, or for just Lake Erie, or find information on a particular topic, such as harmful algal blooms.

This report attempts to expand upon the SOLEC reports by sorting through the set of SOLEC indicators to identify those that have data focusing on the objectives of the Agreement, provide data back to 1987 (or close to that point in time), and meet other criteria for selecting indicators to best serve the needs of this report. The IJC determined that 13 of the 80 SOLEC indicators were useful for this particular purpose. Three other indicators used in this report came from outside of SOLEC. While the SOLEC indicator reports provided much of the material presented in this report, additional discussion was typically added to better describe the relationship to the Agreement's objectives and the methods used to compile the data. For many of the indicators presented, additional literature was reviewed, synthesized, and referenced.

The IJC recognizes that government programs do affect the health of the Great Lakes and that policies adopted by Canada and the United States have been successful in driving observed changes in chemical and biological indicators. Following up on these successes, the IJC recommends that the governments:

- Improve the web-based organization of existing SOLEC indicator reports to enable users to find information more easily.

- Continue to work with the IJC to identify a limited set of core indicators which measure the ecological and human health conditions and stressors most relevant to 2012 Agreement objectives.
- Ensure that resources are made available to collect the monitoring data needed to support these core indicators.
- Commit to establishing goals, targets, or standards for each of the core indicators.
- Provide resources for prevention and remediation actions that are necessary to achieve objectives.

These steps are necessary because sound monitoring data provide information to help protect environmental resources worth billions of dollars.

Selection of Indicators and Approach for this Report

The sixteen ecological indicators were selected by IJC based on existing criteria. Criteria included the availability of historical and spatial information, relevance to Agreement or environmental management objectives, ecological importance (e.g., keystone species), availability of experts to contribute and quality of data.

The indicators selected for this report include measures of status and trends along with the drivers of those trends (the cause of a decline in status or the reason for an improvement). Examples of pressures or stressors are phosphorus loading and atmospheric deposition. Other indicators measure the government's performance, specifically on keeping beaches clean enough to stay open and improving conditions at many degraded areas, called Areas of Concern. Therefore, some of the indicators in this report reflect conditions while others reflect pressures or stressors and a third set reflect performance. Most of the indicators in this report reflect overall trends across the Great Lakes. In addition, considering the inherent variability across this large region, we have included a few indicators that are specific to a particular basin or region (for instance, burrowing mayfly density and phosphorus loading for western Lake Erie).

The accompanying technical reports include 16 chapters, one on each indicator, that were developed by a team of Great Lakes scientists and IJC staff. Most chapters include contributors from both countries, reflecting the shared binational goal to implement the Agreement and protect the Great Lakes. The indicator chapters are organized in four groups: 1) seven chapters on chemical integrity; 2) two on physical integrity; 3) five on biological integrity; and 4) two on evaluating the effectiveness of government programs. Each chapter initially discusses how the indicator relates to the objectives of the 1987 Agreement and then describes why the indicator is important, methods, results, discussion and potential future use of the indicator.

All of the indicators relate to at least one of the general objectives or Annexes of the Agreement and some relate to several objectives. In general, the scientific experts

contributed data and interpretations of data. IJC staff provided input from additional literature review, synthesized information and edited information provided by the experts.

This report represents the IJC's own independent viewpoints and contains IJC's recommendations regarding how the collection, provision and reporting of information can be improved to further facilitate the assessment of progress task. The IJC in formulating its recommendations considered the input of many binational experts and comments from reviewers.

This report is written in language to provide accessible information to federal, state, provincial and local governments as well as private organizations, businesses and individuals. This briefer report is supported by the accompanying technical report at (www.ijc.org/en_/Great_Lakes_Quality), which contains dozens of figures and hundreds of references.

Work on this report was initiated in spring 2011. An early draft of this report was released to the public on the IJC's website and at the 2011 Great Lakes Water Quality Biennial Meeting in Detroit from October 12-14, 2011. The draft report was revised based on comments received from multiple other Great Lakes organizations and subsequent work resulted in another draft report. That draft was revised again based on comments from members of IJC's Great Lakes advisory boards, EC and USEPA. The IJC appreciates the comments from its many reviewers which help provide the perspectives of the Great Lakes community.

SUMMARY OF FINDINGS

Synopsis of Overall Trends

Since 1987, all seven indicators of chemical integrity have shown mostly favorable or stable results. The levels of many persistent toxic chemicals entering the Great Lakes from atmospheric deposition are lower than they were in 1987. Concentrations of most measured persistent toxic chemicals decreased in herring gulls, fish, sediments and mussels. Most reductions occurred from 1987 to 2000, but since 2000 trends vary by chemical, location, and species. However, concentrations of some chemicals of emerging concern have increased since 1987. For instance, concentrations of polybrominated diphenyl ethers (PBDEs, harmful chemicals used as flame retardants) in fish doubled every few years from 1980 to 2000 and then started to decline slightly following voluntary phase-outs of two PBDE formulations by industry.

The five biological indicators show mixed results. From 1987 to 2006, 34 nonnative species became established in the Great Lakes mostly from ballast water discharges. However, no species have been introduced from ballast water since 2006. Populations of the burrowing mayfly and lake sturgeon have started to recover. The number of lake trout in four of the five Great Lakes has been stable overall with year-to-year fluctuations, largely due to stocking, but are still below targets. *Diporeia*, a small shrimp-like invertebrate, a key part of the aquatic food web and a food source for many fish, has almost disappeared.

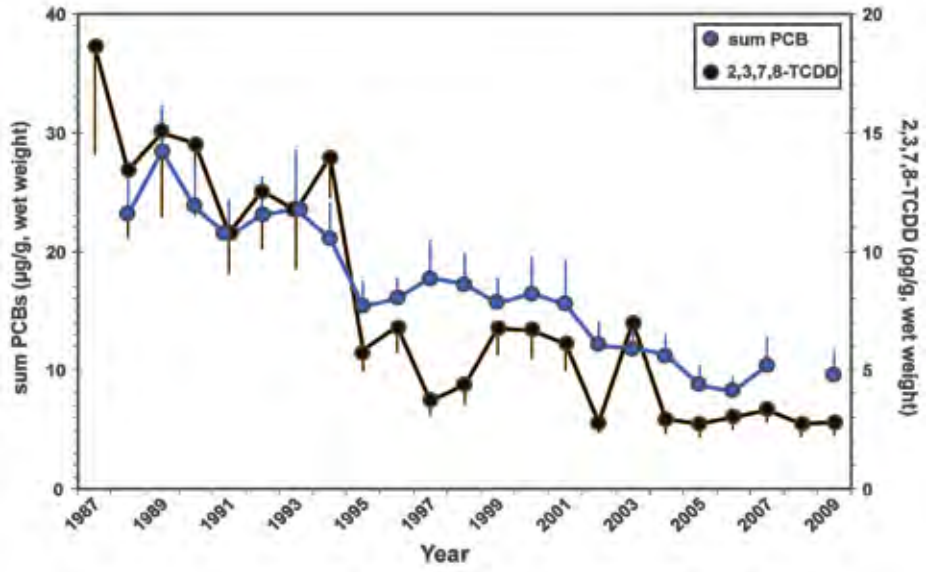
The two physical indicators, surface water temperature and ice cover, both indicate a warming trend, suggesting that global climate change is affecting the Great Lakes. This could lead to shifts in species composition, including increased frequency of harmful algal blooms.

One of the two performance indicators evaluated progress in restoring areas that were previously identified as degraded and officially designated as areas of concern (AOCs). Of the original 43 AOCs, four have been restored to the point that they are no longer considered AOCs and they have been delisted. Approximately 25 percent of the beneficial use impairments in the remaining AOCs have been removed because of the environmental improvements. The other performance indicator evaluated progress in keeping beaches safe and open. Beach closings based on bacteria levels have remained fairly stable over the reporting period of about ten years, but are still common.

Chemical Integrity

Herring gulls

Persistent toxic chemicals such as DDT and PCBs have affected the thickness of egg shells and other aspects of development in many species of fish-eating birds. Herring gulls are colonial waterbirds that are permanent residents of the Great Lakes, and because they eat fish, they accumulate high concentrations of toxic chemicals from the food web. Environment Canada's herring gull egg monitoring program has monitored many contaminants since 1974. The eight discussed here are: PCBs, mercury, dichlorodiphenyl-dichloroethene (DDE), hexachlorobenzene (HCB), heptachlor epoxide (HE), mirex dieldrin, and dioxin. Levels of these chemicals in herring gull eggs have declined by more than 90 percent since 1974 and from 64 percent to 87 percent since 1987. However, in recent years, declines of some chemical concentrations have slowed and mercury levels have remained stable since the mid-1990s. Because herring gulls in polluted areas are experiencing more abnormalities than in cleaner habitats, continued reductions in chemical concentrations are desirable and the monitoring program should continue.



Mean (±standard error) wet weight values of sum PCBs (µg/g) and 2,3,7,8-TCD dioxin (ρg/g) measured in herring gull eggs collected at 15 IJC sampling colonies from 1987-2009 (sample sizes ranged from 13-15 colonies per year). Error bars are symmetrical around the means, but for clarity only a single tail is shown.

Fish consumption restrictions

The levels of persistent toxic chemicals in the edible portions of Great Lakes fish declined between the 1970s and 1987 and for a few years thereafter. Since about 1990, the levels

of contaminants have either declined at a slow rate or have stabilized with year-to-year fluctuations. Numerous restrictive fish consumption advisories aimed at protecting human health from contaminant exposure remain in place for all of the Great Lakes. The majority of these advisories are driven by elevated concentrations of PCBs, including dioxin-like PCBs.

Contaminants in whole fish

Contaminants in whole lake trout and walleye (the entire fish including bones and organs) are measured as an indicator of ecosystem health. Since 1987, concentrations of several persistent toxic chemicals in whole fish have declined at rates of three to nine percent per year. Concentrations of mercury, on the other hand, have been stable or increasing since about 1990. Concentrations of PBDEs in lake trout and walleye rose continuously through the early 2000s and have been declining since that time.

Contaminants in mussels

Bivalve mollusks (shellfish with paired shells) are a key part of environmental monitoring worldwide because they are widely distributed, accumulate persistent contaminants and are easy to collect. Mussel Watch chemistry data collected from 1992-2009 can be used to assess the status and trends of metals, along with legacy and emerging organic contaminants. Most of the Great Lakes sites did not show any trend in either metal or organic contaminant concentrations. However, since a few sites had large declines of contaminant concentrations, many of the metals and organic contaminants showed decreasing trends basinwide.

Contaminants in sediments

Contaminants that are in sediments can harm bottom-dwelling organisms, and the sediments can serve as a source of toxic chemicals in the food chain as prey fish consume bottom dwellers. Successful management actions led to significant declines between the 1970s and the late 1990s in concentrations of many contaminants in sediments, including PCBs, DDT, lead and mercury. It is not clear if levels have continued to decrease since that time. Canada and the United States recently placed more emphasis on understanding the occurrence, distribution and fate of concentrations of chemicals of emerging concern, including brominated flame retardants and perfluoroalkylated substances, because of their potential to harm ecosystems and human health.

Phosphorus loading

Phosphorus loading is an important contributor to excessive algal growth, especially in shallow and nearshore waters of the Great Lakes. Substantial reductions in loading from major wastewater treatment plants have been achieved, but combined sewer overflows still require additional control efforts. Since 1975, the National Center for Water Quality Research has been monitoring Lake Erie tributaries for various parameters, including

total phosphorus (TP) and dissolved reactive phosphorus (DRP). Reduced loading of TP and DRP through 1995 is a sign that control programs were successful. Since that time and especially in the last few years, there has been a reemergence of harmful algal blooms in Lake Erie. These blooms are thought to be attributed to DRP because loadings of TP levels have been stable while loadings of DRP have increased, and DRP is easier for algae to consume. Improved management controls to reduce DRP loading from stormwater events, especially from agricultural lands are needed, along with associated monitoring.

Atmospheric deposition

Atmospheric deposition occurs when pollutants are carried through the air to the Earth's surface. The amount of deposition of most measured persistent toxic chemicals in the Great Lakes basin, as measured by the US-Canada Integrated Atmospheric Deposition Network (IADN), has declined since the 1970s and 1980s, when many were banned in North America. For instance, concentrations of PCBs, have continued to decline and are now at about half the 1990 level, although the rate of decline has slowed significantly. Concentrations of many banned or restricted pesticides, such as lindane and DDT, decreased considerably. Concentrations of several alternative flame retardants are increasing.

Physical Integrity

Surface water temperatures

Significant warming since the mid-1980s is evident in surface temperatures of several of the Great Lakes. The annual average temperature of Great Lakes regional surface waters increased approximately 0.05 to 0.06 degrees C per year between 1985 and 2009. Warming is most pronounced in Lake Superior, the coldest and largest of the Great Lakes.

Ice cover

The Great Lakes are typically covered by ice during part of the winter and early spring. The number of days that each of the Great Lakes is covered by ice has generally declined on all lakes since 1987. One study found substantial declines of ice cover on all Great Lakes between 1973 and 2010, with the smallest decline of 37 percent on Lake St. Clair and the largest of 88 percent on Lake Ontario. Another study similarly found declines in ice cover on all lakes, with Lakes Superior and Michigan averaging less than half the number of days of ice cover than they had in the mid-1970s.

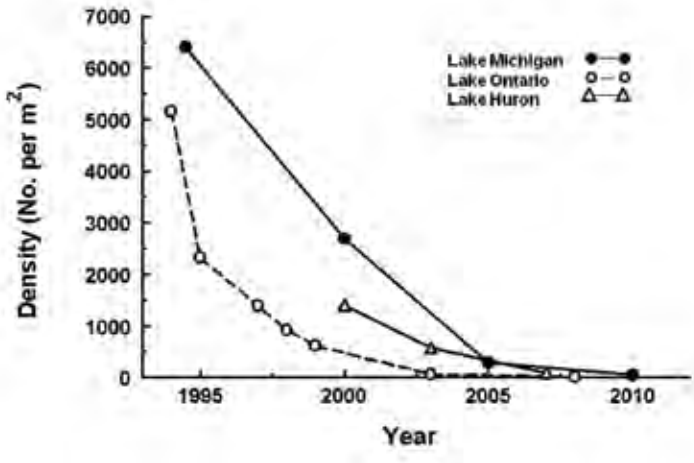
Biological Integrity

Nonnative species

Nonnative species have become established in the Great Lakes and have caused dramatic economic and ecological impacts. The number of nonnative aquatic species in the Great Lakes increased steadily from 1900 until the late 1990s. In the latter portion of this period, nonnative aquatic species that became established were introduced mostly by unregulated ballast water discharges from transoceanic vessels. There were 34 nonnative species introduced since 1987. However, due partly to the implementation of stricter ballast water regulations by Transport Canada, U.S. Coast Guard and St. Lawrence Seaway Authorities, no invasions from ballast water have been detected since 2006. Since the economic and ecological costs of invasive species can be huge and these species are difficult to control once established, prevention and detection activities are essential to stop any discovered species from becoming established.

Diporeia abundance

The bottom-dwelling amphipod (shrimp-like invertebrate) *Diporeia* is a native glacial relict that was once the most abundant bottom-dwelling organism in cold, offshore regions of the Great Lakes. *Diporeia*, with a maximum size of 10 mm, occurs in the upper few centimeters of sediments and feeds mainly on algal material that freshly settles to the bottom from the water column. In turn, *Diporeia* is readily fed upon by most fish species and serves as an important part of the food web. *Diporeia* populations began to decline in Lakes Michigan, Huron, Ontario and Erie in the early 1990s just a few years after zebra and quagga mussels became established. Presently it is completely absent from large areas in each of these lakes. The loss of *Diporeia* has affected the distribution, abundance, growth and condition of fish species that relied on *Diporeia* as a food resource, including commercially important species such as lake whitefish.



Mean density (no. per m^2) of *Diporeia* spp. at 30-90 m in Lakes Michigan, Ontario and Huron.

Hexagenia density

The burrowing mayfly *Hexagenia* is important to fish populations as a food source and is a species sensitive to pollution. These mayflies all but disappeared from most nearshore waters of the Great Lakes in the 1950s because of impacts of increased nutrients that came from urban and industrial activities. High loads of nutrients triggered a series of events resulting in increased growth of algae, settlement of algae to the bottom substrates and its decomposition causing low dissolved oxygen, which leads to losses of mayflies and other lake bottom fauna. In western Lake Erie, the mayflies disappeared in 1953, were absent for 40 years, began to recover in the mid-1990s and have sustained a recovery over the past 15 years. Continued pollution reduction is likely to allow sustained recovery of mayflies in western Lake Erie and other shallow areas of the Great Lakes. Therefore, monitoring of *Hexagenia* is recommended because they are important to fish, reflect the status of water quality in shallow waters and are relatively efficient to sample.

Sturgeon abundance

Lake sturgeon abundance, which fell to one percent of historical levels by the mid-1950s, is beginning to increase in some locations within the Great Lakes. Since the mid-1980s, there has been renewed sturgeon spawning success in several traditional habitats, including the Detroit River, where spawning had not taken place in decades. This is likely due to water quality improvements and successful restoration of habitat or creation of artificial habitat by multiple levels of government and other organizations. However, the species is still listed as threatened or endangered throughout much of the Great Lakes basin, making recovery uncertain. Continued monitoring, habitat restoration and water quality improvements will be necessary to the survival of the species in the basin.

Lake trout abundance

Since the mid-1980s, populations in four of the five Great Lakes have been stable overall, largely because of stocking, but natural reproduction remains below target. The exception is Lake Superior where self-sustaining populations of lake trout have been restored since the mid-1980s. Significant natural reproduction is now evident across most of Lake Huron. Low reproduction rates are evident in Lake Ontario, and little reproduction has been documented for Lakes Michigan and Erie. Major impediments are thought to be excessive adult mortality due to sea lamprey predation, nonnative alewives preying on fry and thiamine deficiency from using alewives as a food source, resulting in early mortality syndrome. Dioxin-like substances may be inhibiting reproduction in the lower lakes.

Indicators of Performance

Delisting areas of concern and removal of beneficial use impairments

Based on Annex 2 of the 1987 Agreement, the federal governments identified 43 areas of concern (AOCs), including 26 in the United States, 12 in Canada and five in shared waters.

These designated areas had suffered serious bacterial or chemical degradation, failed to meet the 1987 Agreement's specific objectives and were likely to have compromised the area's ability to support aquatic life. At the outset, each of the 43 AOCs had at least one and as many as 14 beneficial use impairments (BUIs). Examples of BUIs include loss of fish habitat or contaminants in fish serious enough to prompt consumption warnings. There were a total of 409 BUIs spread across the 43 AOCs. In the past quarter century, only four of the AOCs have been restored to the point that they were delisted, and two of them improved enough to be considered areas in recovery. In the United States, 33 of 255 BUIs have been removed. In Canada, 54 of 154 were removed. Currently both governments are working hard to delist more AOCs and further remove BUIs. To accelerate progress toward meeting these objectives, adequate resources need to be made available by both federal governments, and accountability and responsibility need to be assigned to specific agencies.

Beach closings and advisories

The number of Great Lakes beach closings and advisories declined slightly from 1998 to 2007. The percentage of all US Great Lakes beaches closed more than ten percent of days during the beach season ranged from 12 percent in 1998 to nine percent in 2006-2007. The comparable Ontario figure was 54 percent in 1998 and 42 percent in 2006-2007. These data need to be interpreted with caution, because of changes in the number and set of beaches which were analyzed over time and because different states and Ontario use dissimilar criteria for closures. Disease occurrences related to swimming at Great Lakes beaches may be significantly underreported. The IJC recommends further refinement of testing methods; controls on major pollution sources contributing to beach closings, such as stormwater runoff and sewage overflows; and establishment of a system for data collection on swimming-related disease.

Improving the Assessment of Progress

This assessment of progress focused on 1987-2011 and used data and relevant indicators from that time period. The selected indicators used in this study were supported by reviewers. Yet, under the 2012 Agreement, the IJC would like to better assess progress and improve communication of findings to the public. Ideally, future assessment of progress reports would include discussion and stakeholder buy-in for all the indicators used by IJC, along with clarification of how the data would be collected, analyzed and reported. With that aim in mind, IJC briefly describes the proposed path forward for the government's and the IJC to improve assessments of progress under the 2012 Agreement.

Developing and using a core set of indicators

The IJC recommends that the governments develop their Progress Report of the Parties using a core set of indicators related to the objectives of the 2012 Agreement. Such core indicators provide the public and policy makers with scientifically sound information to make better monitoring, restoration and prevention decisions.

Although there is research and management value in having many indicators, having a core set provides a focus for monitoring, analysis, public communications and enables the tracking of progress for the lifetime of the updated Agreement. Targets, goals or standards should be developed for each of the core indicators and resources should be provided for protection and restoration actions to achieve the goals.

Environmental monitoring

Evaluating progress toward meeting 2012 Agreement objectives depends on a robust, long-term environmental monitoring program that is linked to core indicators. But monitoring has been insufficient for some core indicators related to critical Great Lakes conditions. Some of the data sets maintained by government agencies and discussed in this report lack spatial or temporal coverage, particularly for the identification of trends.

Overall, the Commission recommends the governments allocate sufficient resources to monitor a core set of indicators and enable scientific diagnosis of trends and causes as well as the design of remediation and prevention actions needed to achieve objectives. In particular, the Commission notes the need for indicators of disease resulting from Great Lakes environmental exposures and the need for long-term support for recent government investments in comprehensive lakewide monitoring of phosphorus loadings to Lake Erie and related research.

Reporting to the public

Accurate data analysis and effective communication of results promotes public awareness of challenges to the ecological integrity of the Great Lakes and helps the public understand the importance of effective programs designed to address those challenges. The IJC believes the updated 2012 Agreement provides an opportunity for the governments to make improvements in their reporting in order to inform and engage the public and strengthen accountability, helping to achieve a central goal of the new Agreement. In particular, the IJC recommends that: the governments establish a user-friendly, basinwide system for ecosystem status information; there should be a common system for accessing Great Lakes data, including a portal that is easy for scientists, managers and the technically versed public to use; the governments should improve the organization of the SOLEC reports using a web-based delivery system; and the governments should create a useful reporting and communication system in a "report card" format, providing to the public plain-language descriptions of core indicators and discussion of trends.

Moving Forward under the 2012 Agreement

The recommendations in this report have been aimed at improvements in Great Lakes management, monitoring and reporting by the governments related to fulfilling the objectives of the 2012 Agreement. However, the IJC has also been working to address some of these issues, on its own or in collaboration with the governments.

The IJC is currently examining how it can best fulfill its responsibility for assessing progress under the 2012 Agreement and assessing the extent to which programs and other measures are achieving the Agreement objectives. The IJC has established a working group of IJC advisory board members to assist in making recommendations to governments regarding specific indicators to be included in a limited set of core indicators that would be used for assessing progress toward Agreement objectives. The IJC established a second working group composed primarily of members of it's Health Professionals Advisory Board to identify a set of core human health indicators to recommend to Governments. The IJC has welcomed the input of government representatives in both of these initiatives and hopes that this cooperation will lead to recommendations that are useful to all of the progress reports. The IJC will also review current monitoring programs and make recommendations regarding monitoring to support the proposed indicators.

The Commission has also undertaken a three-year initiative to develop science-based advice to governments on reducing dissolved reactive phosphorus loads to Lake Erie, which should help to address the report's recommendations on phosphorus loading.

To help address the issue of nonnative aquatic species, the IJC, with funding from the Great Lakes Restoration Initiative, has taken action to develop a pilot binational aquatic invasive species rapid response plan with input from representatives of affected U.S. and Canadian jurisdictions.

On the topic of physical integrity, the 2012 Agreement cites linkages between water quality and water quantity and identifies the need to identify, quantify, understand and predict the climate change impacts on the quality of the Waters of the Great Lakes. In this regard, the IJC is considering the recommendations of the International Upper Great Lakes Study that governments implement an adaptive management framework supported by strengthened hydroclimatic modeling and monitoring and that the IJC has a key role to play in this process.

CONCLUSIONS AND RECOMMENDATIONS

The Great Lakes Water Quality Agreements of 1987 and 2012 mandate that the IJC assess the extent to which programs and other measures are achieving the Agreement's objectives, and to provide advice and recommendations on matters related to the Agreement. These responsibilities form the basis of the IJC's advice to the governments of Canada and the United States. For each indicator, IJC provides recommendations regarding the improvement of assessment and reporting. Finally, the chapter presents IJC's recommendations for improving the reporting and assessment of progress under the 2012 Agreement.

Conclusions from Indicator Reports and Recommendations for Managers and Scientists

The indicators tell a mixed story about the attainment of 1987 Great Lakes Water Quality Agreement objectives and yield conclusions that support the IJC's recommendations for monitoring and program management actions. Many government policies have had favorable results. For instance, banning persistent bioaccumulative toxicants (PBTs), like PCBs and DDT, has led to reductions in chemical concentration and increases in colonial waterbird and raptor populations. Conclusions about indicators and accompanying recommendations are sorted by the Agreement's overarching objective of restoring and maintaining the chemical, physical and biological integrity of Great Lakes waters. Some of the recommendations reiterate recommendations that the IJC made in its 15th Biennial Report on Great Lakes Water Quality.

Chemical Integrity

In general, all seven indicators of chemical integrity showed mostly favorable or stable results since 1987. The levels of many persistent toxic chemicals entering the Great Lakes from atmospheric deposition are lower than they were in 1987. Concentrations of most measured PBTs decreased in herring gulls, fish, sediments and mussels. More reductions and more intense declines occurred in the 1987-2000 period than more recently. It is clear that declines of chemical concentrations in biota have slowed since 2000, and, for

a small number of these chemicals, increases may have taken place in the most recent years. Finally, while progress was achieved in reductions of persistent toxic chemicals, concentrations of some chemicals of emerging concern have increased since 1987. The conclusions drawn from the accompanying technical reports (www.ijc.org/en_/Great_Lakes_Quality) and the subsequent IJC recommendations are given below.

Contaminants in herring gull eggs

This indicator reveals large declines of several contaminants since 1987. However, in recent years declines have slowed and mercury levels have remained stable. Despite the reductions, herring gulls in polluted areas are experiencing more abnormalities than herring gulls in cleaner habitat. Since herring gulls are primarily fish-eaters, they reflect chemical concentrations and the condition of the fish they consume.

Herring gull egg indicator data are useful for tracking long-term trends in contaminants across different trophic levels in each of the Great Lakes. As a result, the IJC recommends:

- Governments should protect the herring gull egg monitoring and assessment program from budget cuts and it should continue as an indicator of Great Lakes chemical integrity. The program should be supplemented with monitoring of levels of chemicals of emerging concern. Other research activities should be incorporated into routine monitoring, including evaluation of the avian immune system.

Fish consumption restrictions

This indicator shows that the levels of several PBTs in Great Lakes fish declined between the 1970s and 1987 and for a few years thereafter. Since about 1990, the levels of these contaminants have either declined at a slower rate or have stabilized and, in the case of some emerging PBTs, have increased. Numerous restrictive fish consumption advisories aimed at protecting human health from contaminant exposure remain in place. The IJC recommends:

- State and provincial governments should include chemicals of emerging concern in their monitoring, reporting and decision making with respect to issuing fish consumption advisories.

Contaminants in whole fish

This indicator shows similarly declining contaminant levels. However, many legacy chemicals may be impacting fish health. In order to best protect fish, the IJC recommends:

- Governments should continue monitoring PBTs and improve and seek ways to reduce their exposure pathways to fish.

- Governments should support programs to improve the understanding of how multiple variables (e.g., invasive species, loss of native species and global climate change) affect exposure pathways.
- Governments should support collaborative programs to improve and share understanding of the potential negative ecosystem health effects from exposure to PBTs.

Contaminants in mussels

This indicator shows that levels of many metals and legacy organic contaminants are decreasing basinwide. The IJC recommends:

- Governments intensify future monitoring by adding offshore sites (open water) to complement the data from nearshore sites. The two data sets combined will provide a better assessment of the extent of chemical contamination within the Great Lakes basin. The open water samples would add little additional cost because they would be collected as part of other ongoing offshore monitoring.

Contaminants in sediment cores

Although this indicator shows contaminant levels have declined, the IJC believes further work should be done to evaluate temporal trends. The IJC recommends:

- Governments should continue to examine changes in contaminant concentrations at the surface and at various depths of sediment cores collected from each of the lakes. This work, needs to be maintained to assess changes in loading, identify and track sources of contaminants, and explore opportunities to accelerate the elimination of contaminants. Identification of contaminated sediment hotspots should warrant investigation to pinpoint possible local or subregional sources.

Phosphorus loading

This indicator underscores the contribution phosphorus makes to increased frequency and severity of harmful algal blooms in Lake Erie. Because the data are largely derived from agriculture-intensive tributary watersheds, the IJC believes the indicator report demonstrates the importance of addressing the contribution of runoff from land, particularly from agricultural activities. Reduced loadings and concentrations of available phosphorus, especially dissolved reactive phosphorus, are essential to controlling algal blooms. Without reductions in sources of phosphorus from agricultural runoff into tributaries such as the Maumee and Sandusky Rivers, western Lake Erie will continue to suffer the serious economic and environmental consequences of harmful algal blooms.

Most pollution reduction under the US Clean Water Act has been accomplished through pollution discharge limits imposed via permits for individual facilities or "point sources" such as factories and wastewater treatment plants. While effective in reducing a significant proportion of pollution to Great Lakes tributaries and open lakes,

this approach does not address most nonpoint sources such as pollution runoff from land, including agricultural land. In the United States, the Clean Water Act provides a mechanism for addressing both point and nonpoint sources of pollution for a given water body. The total maximum daily load (TMDL) process involves development of an inventory of sources of a given pollutant for an individual water body, an allocation of the contribution of that pollutant from various point and nonpoint sources to the water body, and a plan to reduce pollution from these sources in order to meet Clean Water Act water quality standards.

Unfortunately, the TMDL process has not been sufficiently implemented in some areas of the Great Lakes that are impacted by nonpoint source pollution. The state of Ohio has not developed and implemented a phosphorus TMDL for western Lake Erie. Other states have also not developed and implemented phosphorus-loading TMDLs for some Great Lakes tributaries. As a result, the IJC recommends:

- Federal, state, and provincial governments should continue to develop and implement best or beneficial management practices to reduce DRP runoff from agricultural lands and to develop and enforce measures to decrease loadings in high risk watersheds.
- Governments should support and encourage farmers to be aware of recommended phosphorus levels for the crops they are growing, to test soil regularly, and to apply fertilizer or manure to soil only when phosphorus is needed.
- Governments should support and encourage development and use of related technologies such as using manure digesters and transporting manure to areas needing fertilizer.
- Governments should develop improved models to more accurately estimate phosphorous loadings to western Lake Erie and to other basins experiencing problems associated with excess phosphorus.
- Governments should collaborate to develop, maintain and share an inventory of effective management actions that are used to better retain nutrients and sediments on the land, especially in watersheds yielding high phosphorus loadings. Examples of management actions include: 1) nutrient-use planning for croplands and livestock operations; and 2) implementing outreach to waterfront residents on better construction and maintenance of septic systems and 3) establishing requirements that septic systems be inspected at time of house sale and upgraded when necessary.
- The states of Ohio, Michigan and Wisconsin should work with USEPA to complete phosphorus TMDLs for the respective water bodies of western Lake Erie, Saginaw Bay and Green Bay.

Atmospheric deposition of toxic contaminants

This indicator shows that the amount of deposition of key persistent toxic chemicals has declined since the 1970s and 1980s, when many were banned in North America. However, emerging contaminants such as persistent compounds in flame retardants are of concern. The IJC recommends:

- Governments should sustain the Integrated Atmospheric Deposition Network (IADN) at historic funding levels. As a long-lived, statistically valid measure of atmospheric deposition of toxic chemicals, IADN and reporting of its data are important to measuring the chemical integrity of the Great Lakes.
- Governments should support research to help identify the origin of contaminants in order to target remediation and prevention actions.

Other chemical integrity recommendations

Although indicators used in this report show that significant progress has been made since 1987 in reducing a number of the historic chemical contaminants, further actions need to be aggressively pursued in order to invest public funds most efficiently. The IJC reiterates chemical policy recommendations from its 15th biennial report:

- Federal governments should develop and implement a process to identify chemicals that are a priority for binational action, consistent with national chemical management programs.
- The governments should supplement existing chemical monitoring programs with biological exposure and effects monitoring to better assess risks of chemicals and chemical mixtures to humans and the environment and to enable assessment of management strategies.
- The governments should continue to invest in research to better understand human health and ecological effects of mixtures of chemicals, including chemicals of emerging concern.
- Governments should increase investments in scientific research to better understand causation of stable or increasing mercury levels in Great Lakes biota and sustain related monitoring and data analysis.
- Governments should continue implementation of standards reducing mercury emissions from coal-fired power plants, the leading domestic sources of anthropogenic mercury.
- Federal, provincial and state governments should invest in communication efforts that educate consumers and provide incentives that encourage them to purchase more environmentally friendly products and services, and practice safer disposal of products (e.g., take-back programs) that contain chemicals of emerging concern.
- Governments should increase investment in wastewater treatment technologies that improve the detection, control, removal and destruction of chemicals of emerging concern.

- Federal governments should work with provincial and state governments through targeted monitoring to identify and track down local sources of pollution for those chemicals whose distribution in the ambient environment suggests local or subregional sources. Ongoing monitoring programs in the Great Lakes connecting channels (e.g., Detroit River, Niagara River) provide valuable information on the success of binational management actions to reduce or eliminate discharge of toxic substances to the Great Lakes.

Physical Integrity

The IJC commends the Parties for beginning to undertake improved monitoring and analysis of physical indicators such as land cover, fish habitat and coastal wetland landscape extent and composition and for reporting results through SOLEC. Physical indicators are essential to determining progress toward 1987 and 2012 Agreement objectives. The conclusions drawn from each of the physical integrity indicator reports and the subsequent management recommendations from the Commission are given below.

Lake surface temperature and ice cover

The data show increasing temperatures and dramatic reductions in ice cover, reflecting a warming trend that could impair native fish populations and have other undesirable impacts. The consensus among scientists is that these observations reflect global climate change. Some jurisdictions have taken actions to mitigate greenhouse gas releases such as the Ontario Green Energy Act and state climate change action plans. However, management actions in the Great Lakes basin can have only limited impacts on this worldwide global phenomenon. Therefore, program managers should seek to understand impacts and implications, and make adaptations to address climate change. The IJC recommends:

- Governments should adopt climate change adaptation strategies and mechanisms that would assist program managers.

To enhance the value of the surface water temperature indicator, the IJC recommends:

- The Parties should routinely conduct analysis of long-term, geographically distributed surface water temperature data with additional monitoring buoys to contribute to the understanding of trends.

Biological Integrity

Biological indicators yielded mixed trends. From 1987 to 2006, 34 nonnative species were introduced into the Great Lakes. Populations of the burrowing mayfly have started to recover, but lake trout populations are consistent with 1987 levels. *Diporeia*, a key part of the aquatic food web and a food source for many fish, has almost disappeared.

Nonnative Aquatic species

This indicator notes the continued introduction of such species over the past 25 years, with success in preventing any establishments from ballast water discharges since 2006. However, recently species have become established from other pathways. The potential for the spreading of such species and new introductions continues to exist, and aquatic invasive species pose a risk of causing further severe economic and aquatic food web impacts. As a result, further government research, control and response actions are warranted.

The IJC recommends that the governments institute these actions to address aquatic invasive species:

- Prevention: The governments should provide incentives for private industry to implement ballast water treatment technologies that further reduce the likelihood of introductions from this pathway. Public education and outreach programs should be expanded to increase awareness of AIS and reduce the spread from live trade and recreational boating. Control measures and legislation are needed to address hull fouling, anti-fouling paints and species sold in live trade.
- Early detection: Governments should sustain a long-term, binational, basinwide AIS early detection program. The program should include research on monitoring techniques and provide training for citizen volunteer monitoring. Risk assessments are needed to assess risk by vector and pathway and direct resources toward particular species and locations.
- Rapid response: Governments should develop and implement a cooperative, binational Great Lakes AIS rapid response plan with harmonized response actions. Each nation should officially designate a lead agency to assure appropriate action is taken in collaboration with the other nation to act without delay when an emergency arises.
- Control: Sustained control actions to prevent the spread of AIS are needed. For instance, continued application of lampricide to control sea lamprey should be conducted. More research on interlake transport of ballast water and ways to address those movements are also needed.

Burrowing mayfly density

This indicator shows that burrowing mayflies (*Hexagenia*) in western Lake Erie, absent for 40 years, began to recover in the mid-1990s and have sustained a recovery over the past 15 years. Continued reductions of pollution and monitoring are likely to confirm recovery of mayflies in western Lake Erie and other areas of the Great Lakes. The IJC recommends that:

- Governments support continued monitoring for *Hexagenia* where they are now found to help document density trends.
- Governments should monitor dissolved oxygen (DO) levels in suitable habitat to identify areas where *Hexagenia* return is anticipated and could be stimulated.

Diporeia abundance

This indicator shows that *Diporeia* (a bottom-dwelling amphipod) populations began to decline in Lakes Michigan, Huron, Ontario and Erie in the early 1990s just a few years after zebra and quagga mussels became established. Presently, it is completely absent from large areas in each of these lakes. The IJC recommends that:

- Until quagga mussel populations decline, governments should decrease the frequency and intensity of monitoring *Diporeia* populations, and more emphasis should be placed on understanding the causes of decline and potential remedies such as monitoring and restoring an alternate species such as *Mysis*.

Lake sturgeon abundance

This indicator shows that sturgeon populations, which fell to one percent of historical levels in the mid-1950, are beginning to increase in some locations within the Great Lakes. Since the mid-1980s, there has been spawning success in several traditional habitats, including the Detroit River, where spawning had not taken place in decades. The IJC recommends:

- Continued habitat restoration and water quality improvements, which will be necessary for the survival of the species in the basin.
- The governments should conduct sustained, long-term monitoring of Great Lakes lake sturgeon populations. Population measurements are needed from a greater and geographically distributed set of locations, particularly spawning streams, where sampling is most efficient. Juvenile populations are an important sampling target.

Lake trout abundance

This indicator shows that since the mid-1980s, populations in four of the five Great Lakes have been stable overall, largely because of stocking; Lake Superior is the exception and now has a self-sustaining population. In Lake Huron there is a trend toward recovery with substantial reproduction in most areas. The IJC recommends:

- Because lake trout is a native top predator fish in four of the Great Lakes - Superior, Michigan, Huron, and Ontario, measuring its abundance serves as an indicator of biological health of those lakes. Continued use of lake trout abundance as an indicator is advisable in the four lakes. For Lake Erie, walleye abundance or harvest data should be the top predator fish indicator.

Indicators of Performance

Areas of concern and beneficial use impairments

One of the program performance indicators is the restoration of beneficial use impairments (BUIs) at Great Lakes areas of concern (AOCs). AOCs were designated by the governments because the areas were degraded for a variety of reasons, including bacteriological pollution, chemical contaminants in fish or habitat loss. Of the 43 original AOCs, four have been restored and two are now considered areas in recovery. Each of the 43 AOCs had at least several beneficial use impairments. In the United States, 33 of 255 BUIs were restored. In Canada, 54 of 154 were restored. The governments have made progress implementing restoration actions to delist AOCs and remove BUIs, but this work needs to be accelerated. The governments have done an excellent job reporting on this indicator, and the results presented in this report are available from Environment Canada and US Environmental Protection Agency websites. The IJC recommends:

- Governments should make resources available for continuing and accelerating progress towards BUI removals and AOC delistings.
- Governments should continue to track and report on this indicator, since removing beneficial use impairments and delisting areas of concern is an objective under the 2012 Agreement.

Beach closings and advisories

This indicator suggests Great Lakes waters are swimmable with significant qualifications. Beach closings based on the presence of indicator bacteria have remained fairly stable over the reporting period of the last 14 years. Although most monitored beaches are open for swimming throughout the summer season, closures are still too common. The IJC recommends that governments take the following measures to enhance public health protection for Great Lakes recreational swimming:

- Develop binational, standardized, basinwide surveillance and monitoring protocols in conjunction with preventive risk management strategies and adopt binational, standardized criteria for beach postings.
- Continue to improve monitoring methods to support real-time assessments of beach water quality and support timely closings to protect beach users.
- Continue research on microbial source tracking, which helps distinguish among the various bacterial sources impacting recreation waters. The findings would help direct source intervention measures.
- Develop a central Great Lakes registry for closings and waterborne disease resulting from swimming at public beaches. Disease occurrences related to use of recreational waters should be reported to the registry. In addition, investigations of the cause of major occurrences should be conducted and reported to the public and to researchers.

CONCLUSIONS REGARDING INDICATORS AND THE REPORTING OF PROGRESS

For the past 25 years, the IJC has issued reports that discuss the importance of indicators for assessing progress under the 1987 Agreement. The assessment of progress made in this report used data and indicators that covered all, or most of the 1987-2012 period. Looking forward, under the 2012 Agreement, the IJC would like to better assess progress under the revised Agreement and improve communication of findings to the public. Ideally, future assessment of progress reports would include discussion and stakeholder buy-in for all the indicators used by IJC, along with clarification of how the data would be collected, analyzed and reported. With these goals in mind, this section sets out the Commission's recommendations for improvements to the reporting of progress made by the governments towards achieving the objectives of the 2012 Agreement.

Selecting a Core Set of Indicators

The IJC recommends that the governments develop their Progress Report of the Parties using a core set of indicators related to the objectives of the 2012 Agreement. The governments have made progress since 1994 in refining indicators and moving toward selection of a core set through the State of the Lakes Ecosystem Conference (SOLEC) process. SOLEC 2011 presented approximately 80 indicators. Although there is research and management value in having many indicators, having a core set provides a focus for monitoring, analysis and public communications. Such core indicators provide the public and policy makers with scientifically sound information to make better monitoring, restoration, and prevention decisions.

These core indicators should be monitored and reported on regularly to enable tracking of progress for the lifetime of the updated Agreement. The governments also need to provide the resources for the prevention and remediation actions that are necessary to achieve the objectives measured by these indicators. Targets, goals or standards should be developed for each of the core indicators and resources should be provided for protection and restoration actions to achieve the goals.

Environmental Monitoring

Evaluating progress toward meeting 2012 Agreement objectives depends on a robust, long-term environmental monitoring program that is linked to core indicators. But monitoring has been insufficient for some core indicators related to critical Great Lakes conditions. Some of the data sets maintained by government agencies and discussed in this report lack spatial or temporal coverage. Phosphorus loading data for western Lake Erie is available only for some tributaries. Other data sets do not extend back to 1987, making it difficult to discern trends over the last 25 years. For example, beach closing data used in SOLEC reports reach back only to 1998.

There are also important gaps in what is routinely measured by governments, academic researchers and others, including human health as affected by the integrity of the Great Lakes. One of the most vital concerns of the public is the safety or risk to human health of exposure to Great Lakes contaminants through fish consumption, drinking water and swimming. Developing indicators of disease resulting from Great Lakes environmental exposures that reflect the best science and communicate meaningful information to the public is an important task for the governments.

Perhaps the most conspicuous example of a monitoring gap is the absence of comprehensive lakewide, long-term monitoring of phosphorus loadings to Lake Erie, which has complicated the choice of prevention and remediation measures. Heidelberg University's National Center for Water Quality Research in Ohio has maintained the only long-term sustained phosphorus monitoring of Lake Erie tributaries, with data reaching back to 1974. But the governments discontinued monitoring of Lake Erie phosphorus loadings in the mid-1990s, and, due to funding constraints, the Heidelberg program monitors only several tributaries. To fully understand the role of various sources of phosphorus to Lake Erie and to develop and implement effective management strategies, the governments must conduct long-term Lake Erie tributary monitoring of loadings. The monitoring must measure total phosphorus, dissolved reactive phosphorus, and also monitor phosphorus concentrations in the open lake.

Both governments have recognized this need and are currently directing additional resources towards phosphorus studies in the Lake Erie basin. Environment Canada's Lakes Nutrient Initiative will help establish current nutrient loadings from Great Lakes tributaries, including tributaries of Lake Erie, and combat the recurrence of toxic algae. The U.S. Great Lakes Restoration Initiative is also funding Lake Erie nutrient monitoring. However, given the history of this particular issue and the possibility that funding may be reduced or eliminated in the future, governments should identify further means to support long-term monitoring of phosphorus in basins experiencing eutrophication issues (e.g., western Lake Erie, Saginaw Bay, Green Bay).

Sound monitoring data provide information to help protect environmental resources worth billions of dollars. Monitoring and assessment efforts along with peer-reviewed science are needed to make wiser management decisions and target limited resources for

restoration and protection of Great Lakes water quality. In addition, monitoring and assessment of resulting data helps the public understand whether the integrity of the Great Lakes basin is improving or deteriorating. The IJC recommends:

- Even in a time of budget austerity, the governments should allocate sufficient resources to monitor a core set of indicators, enable scientific diagnosis of causes of adverse trends and undertake remediation and prevention actions that are needed to achieve objectives.

Reporting to the Public

Development of a core set of Great Lakes ecological indicators is important to serve the public's information needs about the health of the ecosystem. Accurate data analysis and effective communication of results promotes public awareness of challenges to the ecological integrity of the Great Lakes and helps the public understand the importance of effective programs designed to address those challenges. Indicators that are understandable and responsive to public concerns also foster informed public participation in Great Lakes policy development.

The governments should establish a user-friendly, basinwide system for ecosystem status information for scientists, managers, governments, policy makers and the public. The Great Lakes Observing System shows promise for answering this need. The observing system seeks to integrate chemical, biological, physical and hydrologic data; modeling tools; and monitoring programs for maritime, environmental, industry and governmental partners. SOLEC information can be even more useful with additional sorting and by improving the web-based delivery system. The IJC recommends:

- Federal, provincial, state, municipal and other public agencies and Canadian and US academic institutions should develop a common data access system, including a portal that is easy for scientists, managers, and the technically versed public to use. The system should provide electronic access to detailed data sets and tools to enable online searching.
- The governments should improve the organization of the SOLEC reports. Using a web-based delivery system, SOLEC information could be organized in such a manner to link its indicator reports to 2012 Agreement objectives. Also, indicator reports should be sorted temporally, spatially, or by topic to better meet particular needs of resource managers.
- The governments should create a useful reporting and communication system in a "report card" format, providing to the public plain-language descriptions of core indicators and discussion of trends.

The IJC believes the updated 2012 Great Lakes Water Quality Agreement provides an opportunity for the governments to make these two improvements in order to inform and engage the public. In addition, these three recommendations will strengthen accountability,

helping to achieve a central goal of the new Agreement. Providing this information to the public is of particular interest to the IJC due to its responsibilities for consulting with the public about issues related to the quality of the waters of the Great Lakes and engaging with the public to increase awareness of the inherent value of the waters.

Moving Forward under the 2012 Agreement

The recommendations in this report have been aimed at improvements in Great Lakes management, monitoring and reporting by the governments related to fulfilling the objectives of the 2012 Agreement. However, the IJC has also been working to address some of these issues, on its own or in collaboration with the governments.

The current view of IJC is that most of these indicators should have historical data, some should address nearshore and open water conditions, a few of them should reflect human health, and at least one should consider atmospheric deposition. Members of IJC's advisory boards are working on a project in consultation with the governments to identify a recommended set of core indicators.

The IJC has made the assessment of progress toward restoring the Great Lakes one of its priorities for 2012-2015. The Commission is examining how it can best fulfill its responsibility for assessing progress under the 2012 Agreement and assessing the extent to which programs and other measures are achieving the Agreement objectives. The IJC has established a working group of IJC advisory board members to assist in making recommendations to governments regarding specific indicators to be included in a limited set of core indicators for assessing progress toward Agreement objectives. This work is being undertaken with input from SOLEC representatives with the aim of producing a small set of environmental indicators that will draw from, augment and complement the wider set of SOLEC indicators.

The IJC established a second working group composed primarily of members of the it's Health Professionals Advisory Board to identify a set of core human health indicators to recommend to Governments. The IJC has welcomed the input of government representatives in both of these groups and hopes that this cooperation will lead to recommendations that are useful to all the progress reports. In this respect, the governments are already addressing the Commission's recommendation that they work with the IJC to identify a limited set of core indicators which measure the environmental conditions most relevant to 2012 Agreement objectives. The IJC will also review current monitoring programs and make recommendations regarding monitoring to support the proposed indicators.

This selection of core indicators is not intended to replace SOLEC as it is valuable to have additional indicators, beyond the core set for research and resource management purposes. Provided resources are available for addressing the needs of the core indicators, resources could be allocated for monitoring of additional indicators beyond the core set.

These too should have targets and governments should undertake the necessary actions to achieve the targets.

The Commission's 2012-2015 priority work on Lake Erie will also help to address the recommendations on phosphorus loading. The Commission has undertaken a three-year initiative to develop science-based advice to governments on reducing dissolved reactive phosphorus loads to Lake Erie.

To help address the issue of nonnative aquatic species, the IJC has taken action to develop a pilot binational aquatic invasive species rapid response plan with input from representatives of affected U.S. and Canadian jurisdictions. Great Lakes Restoration Initiative funding provided by the USEPA enabled the IJC to take this important step, which provides a foundation for further planning and binational response coordination under Annex 6 of the 2012 Agreement. While the IJC recognizes that prevention is a top priority, it also sees rapid response planning as a necessary backup.

On the topic of physical integrity, the 2012 Agreement cites linkages between water quality and water quantity and identifies the need to identify, quantify, understand, and predict the climate change impacts on the quality of the Waters of the Great Lakes. The need for these linkages is exemplified by the indicators for water temperature and ice cover. The IJC is acutely aware of the challenges presented by the current low water levels in the Great Lakes. In this regard, it is considering the recommendation of the International Upper Great Lakes Study that governments implement an adaptive management framework supported by strengthened hydroclimatic modeling and monitoring and that the IJC has a key role to play in this process.

Concluding Comments

The 16 indicators selected for this report do not tell the entire story of Great Lakes ecosystem health, but offer valuable insights into trends and changes since the 1987 update of the Great Lakes Water Quality Agreement. The IJC believes the data and analysis supporting the indicators also suggest directions for the governments as they implement the 2012 Agreement. The IJC is encouraged and pleased to see that many of the management recommendations put forward in the report either could be, or will specifically be addressed by the Parties under the new 2012 Agreement that was signed as this report was being finalized. For example, all of the recommendations on Aquatic Invasive Species made in this report could be addressed by the governments under Annex 5 and 6 of the 2012 Great Lakes Water Quality Agreement, and some of the recommendations, such as those surrounding Rapid Response, constitute a major part of Annex 6. The IJC looks forward to reviewing the outputs from these new and continuing initiatives.

In particular, the IJC finds that sustained monitoring of a core set of indicators is essential and consistent with the ecosystem indicators called for in Annex 10 of the 2012 Agreement. Policymakers and program managers can best make informed and

cost-effective judgments when sound scientific information about Great Lakes ecosystem health is available.

While indicators can track and communicate environmental improvements, they will be most useful if goals, targets or standards are established for each core indicator. Governments have the responsibility to ensure that adequate resources are made available to implement management actions needed to achieve the established objectives for each core indicator.

Additional indicators beyond the core set will be useful for research and resource management. Since the core indicators will be linked to the objectives of the Agreement, achieving the targets of the indicators will help achieve the objectives of the 2012 Agreement.

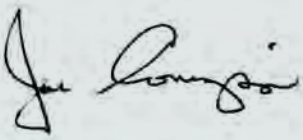
Equally important, sustained monitoring and effective communication of a core set of indicators enables the public to understand Great Lakes ecosystem health. This in turn fosters informed decision making by citizens about both individual actions and the effectiveness of government programs and other measures to restore the health of the Great Lakes ecosystem. The IJC hopes that this report will contribute to the governments' ongoing efforts to improve the application and communication of Great Lakes indicators, leading to fulfillment of the objectives of the 2012 Agreement.

At this point, IJC believes that a comprehensive assessment since the previous amendments in 1987 will provide important information and guidance to help inform the first review cycle of the 2012 protocol amending the Agreement, which was signed in September 2012 as this report was in its final stage of development. In addition, the IJC would like this report to encourage the governments to focus on using a limited set of core indicators for reporting progress towards achieving the objectives of the revised Agreement. The IJC is working on further recommendations in this regard with input from government indicator experts.

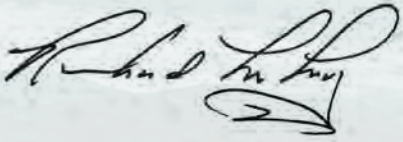
Looking forward to implementation of a newly revised Great Lakes Water Quality Agreement, the IJC hopes this report will offer guidance for an even stronger, more inclusive and collaborative binational commitment to the protection and restoration of the Great Lakes and improvements to the reporting and assessment of progress.

Signed this 15th day of April, 2013 as the 16th Biennial Report on Great Lakes Water Quality and Accompanying Technical Report: Assessment on Progress Made on Restoring and Maintaining Great Lakes Water Quality Since 1987 Pursuant to the Great Lakes Water Quality Agreement of 1978

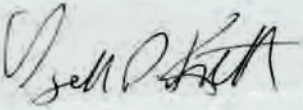
Hon. Lana Pollack
Chair, United States Section



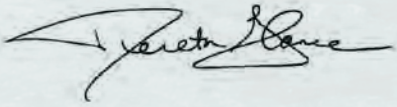
Hon. Joseph Comuzzi
Chair, Canadian Section



Rich Moy
Commissioner



Lyall D. Knott
Commissioner



Dereth Glance
Commissioner

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Lower left photo Microphotograph of benthic organism food for fish — a freshwater worm (*lumbriculidae*) and an amphipod (*diporeia*) swimming at the sediment surface. Lower right photo A Great Lakes tourist.
Front cover photo Present-day Port Stanley, Ontario, a center of commercial fishing.