Effect of Alteration of Natural Water-Level Fluctuations

Indicator #4861

Overall Assessment

Status: **Mixed**

Trend: **Undetermined**

Rationale: **The alteration of natural lake-level fluctuations in the Great Lakes has been a significant driver of degradation in nearshore/coastal wetland vegetation, with the most marked evidence demonstrated in Lake Ontario. However, data gaps exist and preclude a full assessment of impacts.**

Lake-by-Lake Assessment

Lake Superior

Status: Mixed

Trend: Undetermined

Rationale: Nearshore habitat evaluation efforts continue. Data gaps exist in the assessment of impacts on nearshore/coastal wetland vegetation. The on-going International Upper Great Lakes Study will provide an opportunity to develop an improved understanding of the effects of regulation on lake-level changes.

Lake Michigan

Status: Mixed

Trend: Undetermined

Rationale: The on-going International Upper Great Lakes Study is expected to provide an improved understanding of the effects of regulation on the hydrology of the upper Great Lakes system, including indirect influence from regulation on unregulated lakes and physical changes in Saint (St.) Clair River.

Lake Huron

Status: Mixed

Trend: Undetermined

Rationale: The on-going International Upper Great Lakes Study is expected to provide an improved understanding of the effects of regulation on the hydrology of the upper Great Lakes system, including indirect influence from regulation on unregulated lakes and physical changes in St. Clair River.

Lake Erie

Status: Mixed

Trend: Undetermined

Rationale: Nearshore habitat evaluation efforts continue in Lake Erie. A general understanding exists regarding the loss of habitat health in nearshore ecosystems in Lake Erie and St. Clair River/Lake St. Clair/Detroit River connecting channels. Quality habitat is present along the Ontario shoreline of Lake St. Clair.

Lake Ontario

Status: Mixed

Trend: Deteriorating

Rationale: There is loss of biodiversity in upper elevations of most wetlands as documented by the Lake Ontario-St. Lawrence River Study. Data gaps exist in the assessment of impacts on nearshore/coastal wetland vegetation for any new regulation plan implemented.

Purpose

- Identify data gaps with respect to assessing responses of vegetation to changes from natural lake-level fluctuations over time.
- To address data gaps, formulate goals and measurable objectives for designing and implementing a baseline and monitoring program.
- Coordinate with other SOLEC indicators sharing common goals in protecting other nearshore habitats (e.g., fauna) that are impacted by changes from natural variability on water levels.

Ecosystem Objective

The ecosystem objective is to maintain the diverse array of Great Lakes coastal wetlands by allowing, as closely as possible, the natural seasonal and long-term fluctuations of Great Lakes water levels.

State of the Ecosystem

Summary on State of the Great Lakes 2007 report

"Background" presented the knowledge that naturally-fluctuating water levels are essential for maintaining a healthy shoreline ecosystem in the Great Lakes. "Status of Great Lakes Water-Level Fluctuations" presented and discussed hydrographs representing reconstructed (Baedke and Thompson 2000) and recorded water-level histories from each lake. While natural factors affecting lake-levels fluctuations were not specified, water-level regulation on Lakes Superior and Ontario were cited as anthropogenic influences, with mention of other human-related considerations under "Pressure". The significance of naturally-occurring seasonal and long-term water level fluctuations was illustrated in some detail; however, short-term changes occurring outside the hydrologic cycle were not cited (the subject of short-term water-level changes will be discussed later in this report). "Pressure" identified the following issues: withdrawals or diversions of water from the lakes, regulation of the high and low water levels, and climate change. "Management Implications" highlighted the work in progress of the International Lake Ontario-St. Lawrence River Study Board at the time and cited opportunities available to its Environment/Wetlands Working Group for improving the understanding of ecosystem health through out the Great Lakes, emphasizing the need for monitoring.

The information presented next in this report is a supplement to the State of the Great Lakes 2007 report and wil support the indicator's Purpose as stated above.

Background on Great Lakes Water Level Fluctuations

Water-level changes in the Great Lakes, including fluctuations that vary on timescales ranging from hours to millennia, are the result of changes in water supplies and storage in the lakes related to natural factors, in combination with anthropogenic influences. The summary below is a general account of the overall factors affecting water-levels and a limited discussion on water-level history and variability.

The natural factors associated with long-term water-level changes on the lakes include the various environmental processes and related components that contribute to inflow to, outflow from, and storage in the system as part of the

"Great Lakes water balance" (Neff and Killian 2003); and crustal movement caused by isostatic post-glacial rebound, which occurs at variable rates across the basin (Wilcox and others 2007). Within broad scales, water inflow and outflow are dictated by climatically-induced changes that affect the components of the hydrologic cycle, most importantly: over-lake precipitation; the two main components of stream flow, which are surface water runoff and groundwater discharge to streams entering the lake; and evapotranspiration. The flow characteristics of the outlet/connecting channels are also elements of water inflow/outflow for the purpose of the Great Lakes water balance (Neff and Killian 2003, USGS 2005, and Wilcox and others 2007). While the direct flow of surface water runoff to the lakes is considered an insignificant flow component, overland precipitation can be used indirectly to estimate surface water runoff associated with stream flow in areas where stream gagging is incomplete (Neff and Killian 2003). Within the water balance, water storage is a function of changes in water levels and thermal expansion/contraction of water. In the Great Lakes region, groundwater discharge is usually the dominant component of base flow; yet, various human and natural factors also contribute to such flow component (Grannemann and Weaver 1999, and Neff and Killian 2003). The 2007 SOLEC indicator report on "Base flow due to Groundwater Discharge" recognizes the significant contribution of groundwater discharge to stream flow which, in turn, is critical to maintaining lake levels. The discharge of groundwater directly into the Great Lakes, however, has been typically ignored in water-balance calculations because this flow component represents a small contribution relative to other flows (Grannemann and Weaver 1999, and Neff and Killian 2003).

Naturally conforming to the annual hydrologic cycle, seasonal water-level changes are driven by weather variations that result in differences in basin water supply associated with over-lake precipitation, stream flow and evapotranspiration during the year (Neff and Killian 2003, USGS 2005, and Wilcox and others 2007). Storm surges (also known as wind tides) and seiches are responsible for short-term water-level changes (Wilcox and others 2007), which drastically affect water levels without a large change in the volume of water in the lakes. Lasting hours to days, storm surges and seiches displace water within the lake basin (Wilcox and others 2007) due to variations from persistent winds and/or changes in barometric pressure. Effects of seiches are poorly understood, although they can affect zonation of plant communities (Wilcox and others 2007) and create backwater effects on tributaries in nearshore ecosystems (Fenelon and Watson 1993, and Greeman 1995). Additionally, a natural phenomenon known as El Niño/La Niña/Southern Oscillation, or "ENSO", has the capacity to alter both weather and climate around the globe and in the United States (U.S). Extreme phases associated with this phenomenon, El Niño referring to the warm phase and La Niña representing the cool phase, occur at regular intervals of 2-7 years and usually last for 1-3 years. Effects from La Niña brought record snowfall to Great Lakes in 2008.

The effect from anthropogenic factors such as regulation of outflow and water-levels, and dredging and removal of sediment bars along shores (Transport Canada and others 2007) differ from lake to lake (Wilcox and others 2007). Dredging and control structures have had the largest anthropogenic impact on water levels (Wilcox and others 2007) in the system of the Great Lakes and connecting channels. A 2-year study of the St. Clair River is expected to evaluate physical changes with implications from dredging and its effect on water levels among other aspects. Diversions of water into and out of the lakes are very small compared to the total volume of water stored in the lakes (Wilcox and others 2007). Similarly, impacts from surface water withdrawals from the lake and groundwater withdrawals from within the basin are small relative to other water outflow. However, they may have implications with regards to climate change. The water balance for Lake Michigan, for example, estimates 1 cubic meter per second (m3/s) of water diverted into the lake, 212 m3/s of surface water withdrawals, 60 m3/s of groundwater withdrawals, and 170 m3/s of return flows from users (which is reduced by a flow of 91 m3/s that is diverted out of the basin at Chicago, Illinois) (Grannemann and others 2000). In the Great Lakes Basin in the U.S. and Canada, total withdrawals related to thermoelectric power generation include 1,350 m3/s (based on 2002 estimates); however, less than 2 percent of this estimated value is consumed (lost primarily to evaporation) and the remainder is returned to the lakes (Shaffer and Runkle 2007). Hydroelectric power, transportation and water-based recreation involve nonconsumptive uses in which the entire quantity of water withdrawal is returned to the system (USACE 2000). Refer to the SOLEC indicator report on "Water Withdrawals" for further update on this topic. Recent focus on initiatives to study the effects from climate change on the Great Lakes ecosystem will likely facilitate an improved understanding of global scale influences on lake levels (IPCC 2007).

Regulation of water levels on Lakes Superior and Ontario at their outlets seeks to lessen high and low levels (Wilcox and others 2007). Lake Superior water levels have been regulated through much of the period of record, which reflects a pre-regulation data span of only 55 years. In its 1914 Order of Approval, the International Joint Commission (IJC) established the International Lake Superior Board of Control, responsible for setting Lake Superior outflows and overseeing the operations of various control works. The regulation plans implemented by the board of control under the 1914 Order of Approval are as follows: the Sabin's Rule, Rule of Curve P-5, Rule of 1949, and Plan SO-901; Plan 1977 was adopted in 1979 under the 1978-1979 Supplementary Orders of Approval, following reexamination of the 1914 Order of Approval. Plan 1977 was replaced by Plan 1977-A, which is the regulation plan currently in place for Lake Superior. By 1921, full control of the outlet had been achieved through a collection of structures that stretched across St. Mary's River. It, however, is important to understand that the levels and flows in Lake Superior are only controlled to a certain extent (Clites and Quinn 2003 and IJC 2008a). Lake Superior's range of fluctuation during pre-regulation [3.6-foot (ft) (1.1-m) range] does not differ greatly from the post-regulation 4.0-ft (1.2-m) range. It was with the appointment of the International St. Lawrence River Board of Control under the Order of Approval of 1952, as amended in 1956, that Lake Ontario water levels became subject to regulation, although no control was put in place until 1960. Plan 12-A-9 established by the 1956 Order of Approval was never implemented. Plan 1958-A was adopted in 1958 and became operational in 1960; revised versions Plan 1958-C and Plan 1958-D became operational in 1962 and 1963, respectively. Plan 1958-D has remained the regulation plan for the Lake Ontario-St. Lawrence River system since 1963. The current approach to regulation, Plan 1958-D with deviations, has allowed temporary flow changes for specific purposes at the discretion of the board of control's judgment. In pre-regulated Lake Ontario, the range of fluctuations was up to 6.6 ft (2.0 m) as it has continued to present time in Lakes Michigan, Huron and Erie (USGS 2005, and Wilcox and others 2007), changing upon regulation to 4.3 ft (1.3 m) in the years after 1973 (Wilcox and others 2007).

It is widely accepted that the extent of the recorded water-level history is insufficient to capture a comprehensive insight into lake-level variability, unless examined in correlation with reconstructed water-level history such as hydrographs produced by Baedke and Thompson (2000) and reported more recently by Wilcox and others (2007). Rise-and-fall patterns showing some distinctive degree of periodicity in millennial timescale from reconstructed water-level history can be extended into the period of recorded water-level history, up to the present, to be able to recognize fluctuations over the long term (USGS 2005, Wilcox and others 2007, and Sellinger and others 2007). The National Oceanic and Atmospheric Administration (NOAA)'s National Ocean Service maintains water level gages on the U.S. and the Canadian Hydrographic Service (CHS) on Canada (NOAA 2008a and CHS 2008). The Detroit District of the U.S. Army Corps of Engineers (USACE) collaborates with NOAA and CHS on the collection, analysis and dissemination of Great Lakes water level data (USACE 2008). Because Lake Michigan is joined to Lake Huron at the Straits of Mackinac, they are considered one lake hydrologically. Every 25 to 35 years, NOAA's Geodetic Survey adjusts the datum or elevation reference system used to define water levels within the Great Lakes-St. Lawrence River system to correct for crustal rebound. The current datum known as the International Great Lakes Datum of 1985, or "IGLD 1985", was implemented in January 1992 and replaced the previous system, IGLD 1955. The date, 1985, is the central year of the period 1982-1988 in which water level data were collected for preparing the datum revision under the auspices of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (CCGLBHHD). The CCGLBHHD is comprised of committees and representatives from Federal agencies of the U.S. and Canada. The IGLD 1985 has its zero base at Rimouski, Quebec near the mouth of the St. Lawrence River, which roughly corresponds to sea level (CCGLBHHD 1992). The next datum revision is targeted for 2015, probably to be implemented several years later (NOAA 2008b and NOAA 2008c). Figures 1 through 4 show lakewide, monthly-mean water levels for Lake Superior, Lakes Michigan-Huron, Lake Erie and Lake Ontario; all water levels are determined based on a network of water level gages (Table 1) established under the guidance of the CCGLBHHD. Gage locations were selected based on geography, accessibility and data record ensuring the longest common, complete period of record possible for all the lakes (available from 1918 onward).

Hydrographs for recorded lake-level histories for each lake show some similarities of interest (Wilcox and others 2007). Periods of higher lake levels generally occurred in the late 1800's, the late 1920's, the mid-1950's, and from the early 1970's to mid-1980's. Pronounced low lake levels occurred in the mid-1920's, the mid-1930's and the mid-1960's (Wilcox and others 2007), beginning to decline again in 1998 (Sellinger and others 2007). Water levels on Lakes Michigan and Huron have been extremely low since 2000, and Lake Superior was also low in 2007 (Wilcox and others 2007). Some of those extreme levels, especially low, were muted in Lakes Superior and Ontario after inception of regulation in 1914 and 1960, respectively (Wilcox and others 2007). The range of fluctuations and the cyclic pattern of high and low levels on Lake Superior have not been altered as dramatically as on Lake Ontario since both lakes became regulated. Since 1930, however, low lake-levels have been consistently higher on regulated Lake Superior as compared to lower levels on other unregulated lakes, indicating a shift to fluctuations that are more limited in range in the case of Lake Superior (Wilcox and others 2007).

It should be noted that the summary presented represents a simplified discussion on the natural and human-induced factors affecting natural water-level fluctuations, along with a brief account of long-established database efforts between the U.S. and Canada. Future indicator reports will likely provide a more detailed update on the knowledge of hydroclimatic forces driving the water balance for the Great Lakes. There will be opportunities for exploring in more detail the relationships between hydrologic parameters (e.g., precipitation, evapotranspiration, surface water runoff and groundwater discharge) and communicating findings from past and present hydrologic modeling efforts for the Great Lakes. Future discussions will likely elaborate further on global-scale effects, such as climate change and sunspot periodicity.

Status of Effect of Alteration of Natural Water-Level Fluctuations in the Great Lakes

SOLEC 2007 identified the shoreline ecosystems, especially coastal wetlands, as dependant upon water level fluctuations to develop habitat value. Background papers from SOLEC 2007 identified coastal wetlands (including embayments and islands), the lower reaches of all Great Lakes tributaries, and the connecting channels (Edsall 1997) as components of nearshore ecosystems.

Alteration of natural lake-level fluctuations has been equally recognized as a stressor affecting other ecosystem elements (among them shoreline movement, stabilization of sand dunes, fish access to spawning habitat, and availability of waterfowl habitat and nesting areas) as well as recreation, water consumption and other human activities in the Great Lakes. This indicator will limit its focus to the effects on vegetation from the nearshore based on earlier consensus as part of indicator development. However, this report seeks to point out the need to gain a holistic understanding of the effects of changes from natural variability on the diversity of habitat associated with nearshore ecosystems (e.g., fauna habitat from wetlands). Another relevant consideration is the cumulative effect that other stressors may have on nearshore/coastal wetland vegetation (e.g., degradation due to presence of water and sediment contamination, impact from sediment loading, and introduction of non-native species). For example, the 2007 SOLEC indicator report on "Coastal Wetland Plant Community Health" identifies several pressures that lead to degradation of coastal wetlands, among them agriculture, coastal manipulation, and other human development scenarios. Additionally, the importance of climate change has been clearly recognized (IPCC 2007). Most recent updates to the Binational Partnership for Lake Huron and the Lakewide Management Plan (LAMP) for Lakes Superior, Michigan, Erie and Ontario have expressed the need to integrate climate change considerations into decision making.

Four past and present major efforts have been undertaken to address the assessment of coastal/inland wetland in relation to ecosystem health (Paul Bertram; U.S. EPA; personal communication; June 2008). These efforts, some of which have a strict focus on the nearhsore, include the National Monitoring Network and its Lake Michigan Pilot Study (USGS 2008); the Great Lakes Environmental Indicators Project (U.S. EPA 2006); the National Coastal Conditions Assessment (U.S. EPA 2008f); and the wetland inventory and classification effort completed by the Great Lakes Coastal Wetlands Consortium (GLCWC 2003, and GLCWC 2004), followed by its recently developed Great Lakes Coastal Wetlands Monitoring Plan (dated March 2008). These efforts are expected to make progress toward addressing data gaps on the nearshore. Additional evidence has been gathered on species adaptability under changing water-level fluctuation conditions. Wilcox and Nichols (2008) document the ability of some plant species to recolonize exposed areas along the shore during periods of decreased water levels. Further gaps can be addressed in areas where limited knowledge exists, such as the effect of low lake water levels on the Great Lakes island habitats (USACE 2005). The 2007 SOLEC indicator report on "Area, Quality and Protection of Special Lakeshore Communities-Islands" presented the first detailed binational map and database of Great Lakes islands, while calling attention to indicator needs. Similarly, the "Conservation Blueprint of the Great Lakes" (TNC 2008) which was recently issued by the Nature Conservancy may prove to be a useful tool to help define indicator needs. It, however, would be valuable to integrate in some manner these efforts with any future implementation of a baseline and monitoring program related to this indicator. Noteworthy are the examples of coastal wetlands in the Great Lakes that have been recognized internationally.

For further details, refer to summaries below for each of the Great Lakes.

Summary of Effects by Lake

Lake Superior

Recent experiences from a restoration project in Nipigon River point out to the need for an improved understanding of the interactions between surface water and groundwater locally. At Nipigon River, springs provide a source of water supply for spawning habitat in the lower portion of the tributary (U.S. EPA 2008a). A conservation plan will be developed to protect critical lake and tributary habitat (U.S. EPA 2008a). Also, the input from seiches may play a role in the distribution of organic matter in coastal wetlands as seen in some areas in Lake Superior (Trebitz and others 2005).

In October 2007, the Government of Canada announced the creation of the country's newest National Marine Conservation Area (NMCA). More than 10,000 square kilometers (km^2) of Lake Superior, including the lakebed, islands, and north shorelands within the NMCA boundaries, make up the largest freshwater marine protected area in the world. Protected areas such as NMCA may be valuable for drawing effect-response relationships to support baseline/monitoring strategies.

In February 2007, the IJC appointed the International Upper Great Lakes Study Board to conduct a 5-year study to evaluate options for regulation of Lake Superior outflows and water levels in a manner that benefits affected interests in the upper Great Lakes. The study board is expected to integrate all relevant information needed to evaluate the system involving Lakes Superior, Michigan, Huron, and Erie, and their connecting channels (St. Mary's River, St. Clair River, Lake St. Clair, Detroit River and Niagara River), while proceeding with the investigation of physical changes in the St. Clair River on a faster 2-year track. Conditions in St. Clair River will be evaluated as one factor possibly affecting water levels and flows on Lakes Huron and Michigan. The study board will also evaluate whether remediation measures may be warranted in St. Clair River.

Lake Michigan

Since LAMP 2000, the Lake Michigan LAMP has presented a cross walk between the SOLEC indicators and the LAMP goals, demonstrating a strong alignment. As part of the Great Lakes Basin Study under its National Water Availability and Use Program, the USGS is developing a groundwater-flow model effort for the Lake Michigan subbasin to assess water availability and use. This effort will include simulation techniques addressing the interactions of groundwater and surface water at the appropriate scale (USGS 2005). Moreover, beginning with Lake Michigan in 2008, U.S. EPA has initiated additional nearshore monitoring using a towed sensor package, known as "Triaxus", that will help provide a three-dimensional characterization of basic physical, chemical and biological aspects of the nearshore, as well as sonar-mapping of underwater habitat (U.S. EPA 2008b). These studies will assist in expanding the understanding of habitat in nearshore areas. Thus, the results from these studies will be useful for developing further knowledge on the effects of alteration of natural water level fluctuations on nearshore/coastal wetland vegetation.

The Great Lakes Coastal Wetland Consortium identified 800 coastal wetlands for Lake Michigan (U.S. EPA 2008c). The health of these wetlands has not been assessed relative to this indicator. Historical patterns in the nearshore include changes in water levels from seiches. Effects from seiches, for example, have been observed in the Grand Calumet River/Indiana Harbor Canal from Indiana, although generally with amplitudes smaller than the approximate, maximum of 3.0 ft (0.9 m) observed in other parts of Lake Michigan. Fenelon and Watson (1993) and Greeman (1995) report that during the record-high Lake Michigan levels of 1985-1987, backwater effects were observed as much as 11 miles (18 km) upstream on the East Branch of the Grand Calumet River and 7 miles (11 km) upstream on the West Branch.

The Lake Michigan LAMP identifies the expectation that an increase in evaporation rates due to decline on winter ice coverage in the Great Lakes will likely result in lowering of lake levels, calling attention to the need for continued coordination between the LAMP and SOLEC indicators on this issue.

Refer to above discussion under Lake Superior regarding the 5-year International Upper Great Lakes Study.

Lake Huron

The Great Lakes Coastal Wetland Consortium identified 1255 coastal wetlands for Lake Huron, which along with identified Ontario wetlands represent the greatest amount of coastal wetlands relative to other Great Lakes on the Canadian shoreline (U.S. EPA 2008c). The health of these wetlands has not been assessed relative to this indicator.

Refer to above discussion under Lake Superior regarding the International Upper Great Lakes Study.

Lake Erie

Wetland losses have been more pronounced in the western part of Lake Erie and the connecting channels as a result of the permanent flooding caused by isostatic rebound. Within its natural system, Lake Erie is most susceptible to storm surges and seiches compared to the rest of the lakes, due to its east-west orientation with its generally shallow western end in an area of prevailing westerly winds (USACE 2000). Historically, extreme seiches have been recorded in Lake Erie with amplitudes as large as 5 m.

Along with the lake-influenced portion of the Great Lakes tributaries and the rest of connecting channels, Lake St. Clair is considered part of the nearshore waters because of its shallow depth precluding the presence of vertical thermal stratification, receiving inflow from Lake Huron through the St. Clair River (Edsall 1997, and U.S. EPA 2008d). Wetlands and agriculture dominate along the Ontario shoreline of Lake St. Clair (U.S. EPA 2004).

The Long Point complex and Point Pelee on the north shore of Lake Erie and the National Wildlife Area on Lake St. Clair are ecosystems being recognized on a global scale because of their outstanding biological significance. Long Point has also been designated a United Nations Environmental Scientific Collaboration Organization (UNESCO) Biosphere Reserve (UNESCO 2008).

The Lake Erie LAMP Indicator Task Group has developed an indicator matrix that spreads across five habitat zones, among them coastal wetlands and nearshore. This effort will build upon work from the Great Lakes Environmental Indicator Project (U.S. EPA 2006). Additionally, an integrated habitat classification system and binational map will be developed for the Lake Erie Basin (U.S. EPA 2008d).

Refer to above discussion under Lake Superior regarding the International Upper Great Lakes Study.

Lake Ontario

Cattail has replaced more diverse habitat at upper elevations in nearly all wetlands in Lake Ontario (Wilcox and others 2005, 2007 and 2008; and U.S. EPA 2008e) as a result of the permanent flooding caused by the creation of the St. Lawrence Seaway.

In 2000, in the face of growing dissatisfaction from some interests and the lacking of a comprehensive assessment of regulation for about half a century, the International Lake Ontario-St. Lawrence River Study Board initiated a 5-year study for the IJC, by which it was appointed. At the time of SOLEC 2007, the study was underway to evaluate the procedures and criteria used to regulate the outflows of Lake Ontario and the management of water levels of the lake and the St. Lawrence River, taking into account the impact of regulation on affected interests. To meet its objective, the study board gathered and, as warranted, developed the technical information necessary for gaining an improved understanding of the impact of regulation on the system. For example, wetland predictive models were constructed to assist in predicting the responses of wetland plant communities to the proposed new water-level regulation plans (Wilcox and Xie 2007). The predictive model was also incorporated into faunal predictive models (LimnoTech 2005). Among the equally-considered interests in the IJC study were coastal properties; commercial navigation; domestic, industrial and municipal water uses; the environment; hydroelectric power; and recreational boating and tourism. Before concluding its assessment, the study board presented three candidate regulation plans, Plans A, B and D, holding discussion at public meetings in summer 2005.

Based on public input, the study board developed new plans (Plans A+, B+ and D+), which became incorporated into its final report to the IJC in May 2006, along with an invitation for public comments. The IJC subsequently consulted some of the study experts to develop the two additional plans: D+ variant, called Plan 2007, and a B+ variant. Upon deliberation and consideration of public comments, the IJC has released a proposed new Order of Approval and Plan 2007, with an invitation for public comment until July 11, 2008. In the IJC’s view, Plan 2007 would provide additional environmental benefits (e.g., greater wetland diversity along the shores of Lake Ontario) without significant changes to the level of protection and benefits that are currently being provided to other interests in the current plan, Plan 1958-D with deviations. An element of the plan being highlighted as an environmental advantage is the inducement of a purported significant difference in hydrology as compared to current water level regulation, allowing a decline in water levels greater than what Lake Ontario has been experiencing during dryer summers for a typical 20-30 year period. As pointed out by the IJC, this decline in water levels would be expected to provide opportunities for more diverse habitat. However, great public controversy exists over the proposed plan because of competing stakeholder interests. Environmental groups consider that the IJC has failed the people and the environment by proposing Plan 2007 (Caddick and others 2008). Plan 2007 also reduces lake levels from late autumn through early spring even more that the current plan and would negatively impact muskrat over-wintering and fish that spawn in wetlands in spring (Douglas A. Wilcox; USGS; personal communication; July 2008).

Pressures

An increasingly prominent area where knowledge is limited with respect to alteration of natural water-level fluctuations is climate change.

In the view of environmental groups, Plan 2007 calls for regulation that does not allow sufficient natural variability on water levels for improved wetland biodiversity, favored access to fish spawning grounds during the breeding season, and enhanced connectivity between aquatic and terrestrial habitats essential for wintering mammals in the wetland.

A final peer-reviewed report on the St. Clair River study is expected in June 2009. The remaining scope of the International Upper Great Lakes Study would be completed by 2013.

Management Implications

The upcoming 50th anniversary of the opening of the St. Lawrence Seaway brings more into focus the challenges for balancing public interest on the Lake Ontario-St. Lawrence River system, while ensuring adequate protection of the Great Lakes ecosystem, more critically the nearshore.

Groundwater that discharges to tributaries and later flows toward and into the Great Lakes affects stream flow on a longer time scale than surface water runoff. This consideration adds complexity to the efforts to help define water availability and its relation to changes in lake levels; this could be especially important under certain climate change scenarios. Similarly, water diversions and withdrawals may have implications with respect to climate change overtime.

Declining water levels may have an effect on water quality (e.g., increased loading of nutrients, contaminants and sediment) which, in turn, may aggravate stress conditions in nearshore/coastal wetland vegetation.

Wetland predictive models prepared over the Lake Ontario and St. Lawrence River shoreline can be expanded to the rest of the Great Lakes as a desired approach in terms of consistency and continuity (refer to Summary of Effects by Lake). Similarly, coordination can be fostered among on-going wetland assessment efforts, such as the GLCWC's Great Lakes Coastal Wetland Monitoring Plan (GLCWC 2004 and 2003), the IJC's proposed Adaptive Management for the Lake Ontario-St. Lawrence River System (IJC 2008b), and the development of a habitat classification system and binational map supporting the Lake Erie's LAMP (U.S. EPA 2008d). As expressed earlier, it would be desirable to align under a comprehensive set of goals and objectives this indicator project and other efforts across habitats in the nearshore ecosystem that may have the task of assessing effects from changes in water levels. Generally, piecemeal approaches may not facilitate a holistic understanding of issues, leading to duplication of effort that interferes with adaptive management. U.S. EPA requires the use of a systematic planning process for collection of environmental data and prefers that most project planning be accomplished using the DQO process (U.S. EPA 2000).

With the expected change in regulations for Lakes Ontario and, possibly, Lake Superior, the ability to effectively monitor responses of nearshore/coastal wetland vegetation will be essential for confirming that new plans, when implemented, represent an improvement over the current regulations. The outline below attempts to pose some of the design questions for a baseline and monitoring program to assist with further development of this indicator.

Identification of data gaps A suggested conceptual model would establish stressor-receptor relationship(s). Such relationship(s) would identify "alteration of natural water-level fluctuations" as the stressor; "vegetation" as the receptor, specifically coastal wetlands and other plant habitat in nearshore ecosystems; and "degradation of vegetation" as a measurable effect/response.

Goals, objectives and measures Some key planning considerations would include using quality assurance/quality control principles to ensure that the data are scientifically defensible; adopting consistent, standardized methods; and defining short- and long-term objectives among others.

Baseline and monitoring Establish baseline conditions to monitor changes in vegetation. Although challenging, building "categories" of monitoring sites and corresponding reference sites would facilitate stressor characterization, to the extent possible, with emphasis on regulated and unregulated conditions, evolving regulation, indirect influence from regulation on unregulated lakes, other multi-factors contributing to changes from natural variability (e.g., changes in bathymetry caused by dredging), other stressors (e.g., presence of contamination),and global scale climate change. Select baseline and monitoring parameters that are useful in understanding effect on vegetation and discerning trends: updated, recorded water-level history; plant species assemblage; physical expression of stressor (e.g., magnitude of exposed shoreline); and biodiversity among others.

Comments from the author(s)

In light of the recently initiated International Upper Great Lakes Study, the lake-by-lake assessment should include the St. Clair River/Lake St. Clair/Detroit River connecting channels as a separate category (e.g., connecting channel assessment) to accommodate anticipated complexity in the future. For the purpose of this report, the mentioned connecting channels are included in the assessment of Lake Erie.

The title of this indicator was revised as follows: **Effects of Alteration of Natural Water-Level Fluctuations**. The proposed revised title would be more informative for the public and would more closely reflect the indicator's purpose. An alternate title enhancement would be to identify the ecosystem that is relevant to this indicator by adding a term that would capture the different lake-effect habitat zones in the Great Lakes. An example of a suggestion would be: **Effects of Alteration of Natural Water-Level Fluctuations in Nearshore Ecosystems**. The need for consistency with the **Ecosystem Objective** is also noted (see also comment below suggesting the need for clarification of terminology). Moreover, the **Purpose** of this indicator was updated but may need further refinement as more progress on indicator development is made.

Some clarification would be helpful regarding what may be most adequate terminology to describe the ecosystem in association with the plant habitat that this indicator is protecting (e.g., coastal wetlands, nearshore aquatic). For example, the SOLEC indicator category assessment for "Coastal Zones and Aquatic Habitats" links nearshore aquatic and coastal wetlands to coastal zones as a broader category. Refer to this indicator's discussion under **State of the Ecosystem.**

Assessing Data Quality

Insert "x" under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources	X					
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin	X					
5. Data obtained from sources within the U.S. are comparable to those from Canada	X					
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report	X					
Clarifying Notes: The quality of water level data is subject to the U.S. Office of Management and Budget's government-wide policy on quality of information disseminated to the public, and Canada's Hydrographic Information Network national quality control.						

Acknowledgments

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Lake Superior Gages
Duluth, Minnesota; Marquette and Point Iroquois, Michigan; Michipicoten and Thunder Bay, Ontario
Lakes Michigan - Huron Gages
Harbor Beach, Mackinaw City and Ludington, Michigan; Milwaukee, Wisconsin; Thessalon and Tobermory, Ontario
Lake Erie Gages
Toledo and Fairport, Ohio; Port Stanley and Port Colborne, Ontario
Lake Ontario Gages
Rochester and Oswego, New York; Port Weller, Toronto, Cobourg and Kingston, Ontario

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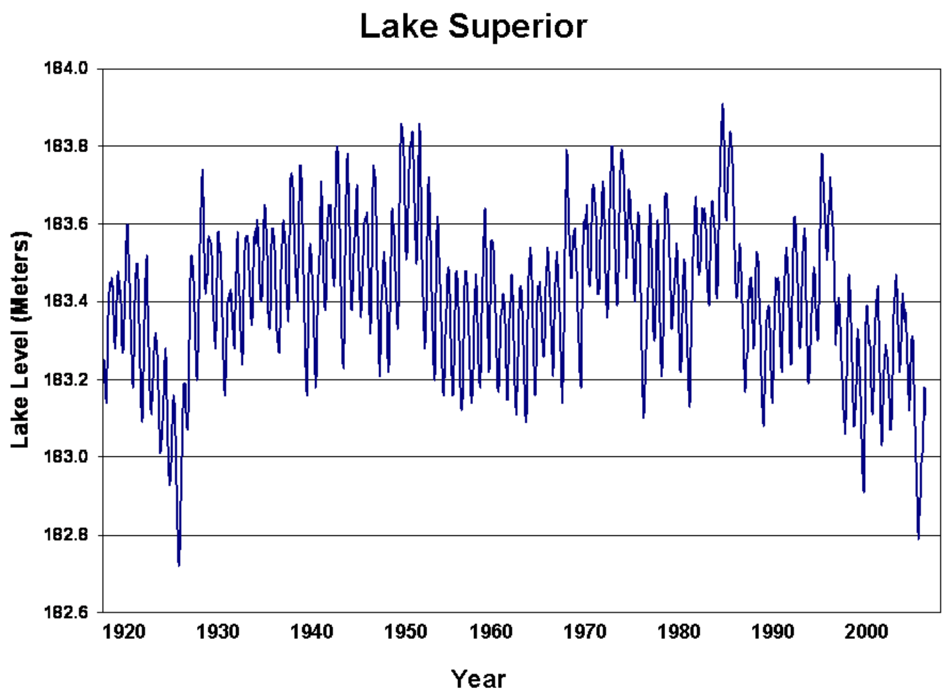

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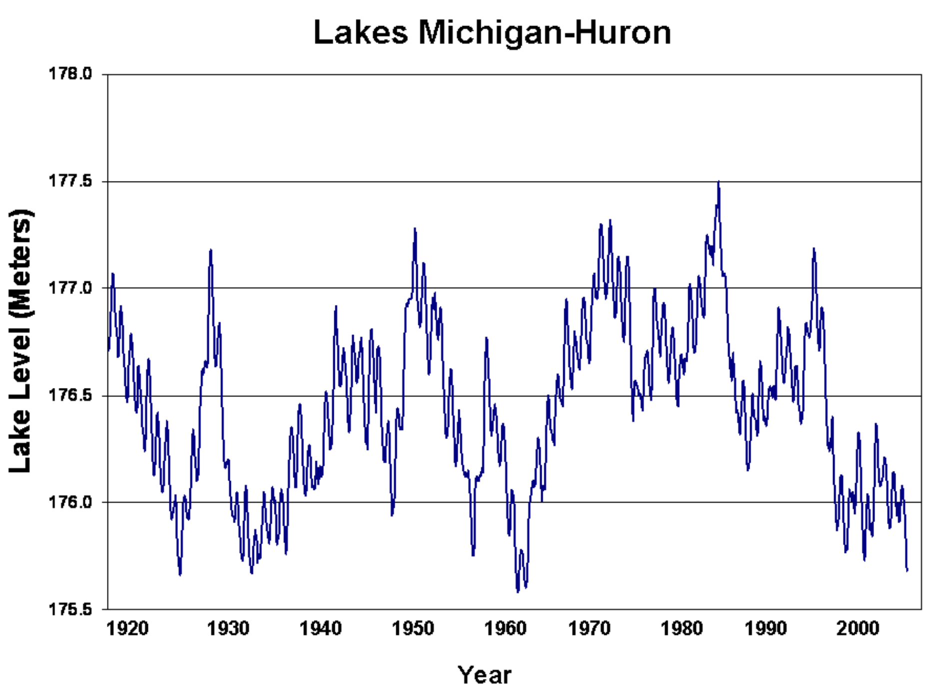

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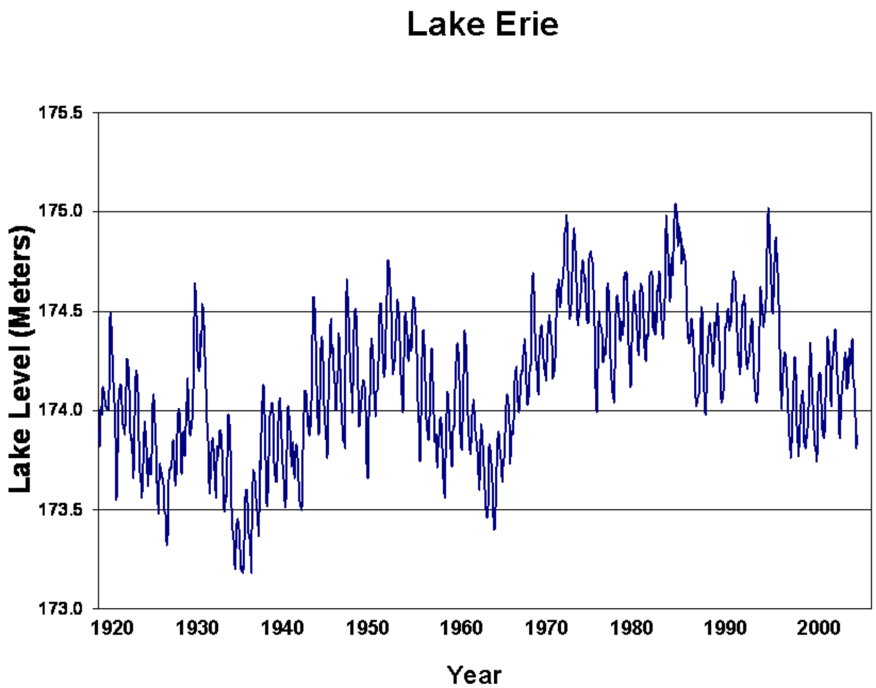

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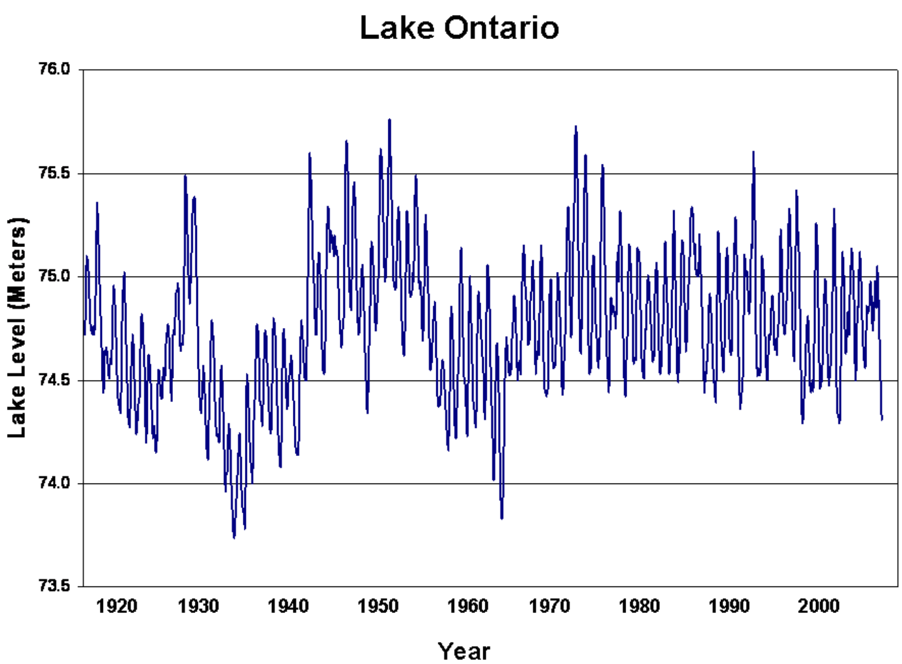

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