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Commentary

A brief history of the U.S. EPA Great Lakes National Program Office's water quality survey

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ABSTRACT

The U.S. Environmental Protection Agency Great Lakes National Program Office (GLNPO) water quality survey (WQS) constitutes the longest-running, most extensive monitoring of water quality and the lower trophic level biota of the Laurentian Great Lakes, and has been instrumental in tracking shifts in nutrients and the lower food web over the past several decades. The initial impetus for regular monitoring of the Great Lakes was provided by the 1972 Great Lakes Water Quality Agreement (GLWQA) which asked the parties to develop monitoring and surveillance programs to ensure compliance with the goals of the agreement. The resulting monitoring plan, eventually known as the Great Lakes International Surveillance Plan (GLISP), envisioned a nine-year rotation of intensive surveys of the five lakes. A broadening of the scope of the GLWQA in 1978 and the completion of the first nine-year cycle of sampling, prompted reappraisals of the GLISP. During this pause, and using knowledge gained from GLISP, GLNPO initiated an annual WQS with the narrower focus of tracking water quality changes and plankton communities in the offshore waters of the lakes. Beginning in 1983 with lakes Erie, Huron, and Michigan, the WQS added Lake Ontario in 1986 and Lake Superior in 1992, evolving into its current form in which all five lakes are sampled twice a year. The WQS is unique in that all five lakes are sampled by one agency, using one vessel and one principal laboratory for each parameter group, and represents an invaluable resource for managing and understanding the Great Lakes.

Introduction

The U.S. Environmental Protection Agency (U.S. EPA) Great Lakes National Program Office (GLNPO) has been conducting an annual water quality survey (WQS) of the offshore waters of the Laurentian Great Lakes for over 35 years. Beginning in 1983, these surveys constitute the longest-running, most extensive monitoring of water quality and the lower trophic level biota of the Laurentian Great Lakes. Data from these surveys have played a major role in tracking shifts in water quality and the lower food web, as well as in identifying changes brought about by aquatic invasive species and in the identification of new non-native aquatic species (Barbiero et al., 2014, 2012, 2011a, 2011b, 2009, 2006, 2002; Barbiero and Rockwell, 2008; Barbiero and Tuchman, 2004; Barbiero and Warren, 2011; Bunnell et al., 2014; Connolly et al., 2017a, 2017b; Makarewicz and Bertram, 1991; Makarewicz et al., 1995; Makarewicz et al., 2000; Reavie et al., 2014; Rockwell et al., 2005). Here we provide a historical context for the development of the WQS, which supports two of GLNPO's long-term monitoring programs: the Great Lakes Biology Monitoring Program and the Great Lakes Water Quality Monitoring Program. GLNPO also conducts monitoring and surveillance programs of other interrelated aspects of the Great Lakes ecosystem, including programs to track trends in contaminant levels in different media (Great Lakes Fish Monitoring and Surveillance Program, Murphy et al., 2018; Integrated Atmospheric Deposition Network, Guo et al., 2018; and Great Lakes Sediment Surveillance Program, Li et al., 2018); to monitor hypoxia in Lake Erie's central basin (Lake Erie Dissolved Oxygen Monitoring Program); and to track changes in the health of coastal wetlands (Great Lakes Coastal Wetland Monitoring Program, Uzarski et al., 2017). The focus of this paper is on the WQS.

Great Lakes Water Quality Agreement

Our history of the GLNPO WQS begins with the Great Lakes Water Quality Agreement (GLWQA, or "The Agreement"), which provides the context for long-term monitoring of the Great Lakes. The GLWQA was signed by U.S. President R.M. Nixon and Canadian Prime Minister P. Trudeau on April 15, 1972 and is widely recognized as a pioneering effort to control pollution in a shared ecosystem (Weiss, 1989). While

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the Agreement has been characterized as the first multi-national agreement designed to protect and resuscitate a shared environmental resource (Holden, 1972), it had been preceded by the Boundary Waters Treaty (BWT) of 1909. Primarily intended to resolve disputes between the United States and Great Britain concerning navigation rights, use and diversion of water, and maintenance of water levels in shared waters of the United States and Canada, the BWT did contain a reference to pollution (in Article IV, which stated that waters "…shall not be polluted on either side to the injury of health or property on the other" (IJC, 2014)). This reference was used as the basis for several assessments of transboundary pollution problems in the Great Lakes prior to the GLWQA. The BWT also established the International Joint Commission (IJC) to provide impartial advice to the governments related to issues regarding the boundary waters between the two countries. The BWT granted broad purview to the IJC, authorizing it to investigate any questions or matters referred to it by either nation, although the resulting recommendations were to be non-binding and without 'the color of law' (Buhi and Feng, 2009).

The original GLWQA, as established in 1972 under the BWT, set specific water quality objectives for a limited number of parameters, included interim objectives for a wider variety of substances, and called for control of pollution from industrial sources, shipping and dredging activities, and onshore and offshore facilities, among other things. It also established two advisory boards under the IJC, a Great Lakes Water Quality Board (GLWQB), of which EPA Region V Administrator Francis Mayo was appointed co-chair, as well as a Research Advisory Board (Article VII). The agreement also charged the IJC, assisted by these two advisory boards, with two specific studies: assessing water quality impacts of land use activities in the Great Lakes, and assessing water quality specifically in Lake Superior and Lake Huron.

Among the more detailed aspects of the 1972 GLWQA was a call for a reduction in phosphorus loading to the Great Lakes, with specific annual goals specified in Annex 2. A general provision for "monitoring, surveillance and enforcement activities necessary to ensure compliance with the foregoing programs and measures," to be completed or in process of implementation by December 31, 1975, was also included in Article V, 1 (a) (v), while Annex 2 more specifically required the signatory parties to "continue to monitor the extent of eutrophication in the Great Lakes System and the progress being made in reducing or preventing it". This established both a focus on phosphorus reduction, and a resultant need for monitoring to assess the efficacy of that reduction.

In response to the requirement for monitoring under the GLWQA, a Surveillance Subcommittee of the GLWQB provided an initial outline for a coordinated, international surveillance program for the Great Lakes (GLWQB, 1975). This GLWQB report identified three water quality issues that the surveillance programs must address: the acceleration of eutrophication or maintenance of a particular trophic state, the presence and impact of toxic substances in the system, and the impairment of water quality by total dissolved and suspended solids introduced into the lakes by human activities. A wide range of monitoring activities was recommended. Whole lake monitoring, which is of most interest here, was meant to measure the water quality of the lakes to determine levels and trends of chemical, physical and biological constituents, particularly as they relate to eutrophication, indicate emerging problems and the effectiveness of remedial programs in the Great Lakes Basin, and measure and calculate loadings and material balances for water quality management. The report called for annual 'impact surveillance' of open waters of all lakes, with intensive surveys every five years for lakes Ontario, Erie and Michigan, and at longer intervals for lakes Superior and Huron due to their longer response times to changes (GLWQB, 1975). At this point, details for a surveillance plan were provided only for Lake Erie, with plans for the other lakes to be drafted in turn and published separately.

The first intensive water quality sampling carried out in the context of the GLWQB's long-term monitoring plan was conducted in Lake Michigan in 1976–1977 (Rockwell et al., 1980). This effort was coordinated by a nascent GLNPO, which was established in 1977 (U.S. EPA, 1978) as a separate office in EPA focused on the Great Lakes. Sampling included 12 open lake cruises on the southern basin of the lake conducted by GLNPO, five open lake cruises in the northern basin conducted by the University of Michigan, Great Lakes Research Division (Stoermer and Stevenson, 1979; Stoermer and Tuchman, 1979), three nearshore surveys in Green Bay conducted by the Michigan Department of Natural Resources (Kenaga et al., 1983), as well as other related studies. The report cited the requirement for eutrophication monitoring under the GLWQA, with authority for EPA's role given as the Federal Water Pollution Control Act (Rockwell et al., 1980) which became commonly known after amendment in 1977 as the Clean Water Act (Copeland, 2016). An important finding of this intensive study was the occurrence of large inter-annual changes in total phosphorus in the offshore waters, which called into question the adequacy of monitoring plans with multi-year gaps.

Concurrent with the initiation of the Lake Michigan intensive survey, the GLWQB held a workshop in 1976 to solicit ideas and opinions from agencies and organizations to build on the 1975 outline and help the Surveillance Subcommittee develop a final plan (IJC, 1977). Among the main conclusions that resulted were (a) two levels of monitoring would be needed: a less intensive monitoring program for parameters requiring continual examination, and a more intensive program focusing on a single lake/river; (b) monitoring should be uniquely tailored to each lake; (c) greater emphasis was needed on biological monitoring; and (d) increased monitoring of the nearshore was needed. The workshop participants also identified insufficient coordination among sampling agencies with limited geographical purviews leading to an inability to assess quality of an entire lake or connecting channel, as well as a lack of emphasis on analysis and interpretation of data.

Taking into account input from this workshop, the GLWQB developed a more detailed surveillance program (GLWQB, 1976) which called for monitoring of all five Great Lakes on a nine-year rotational basis, with two-year intensive offshore surveys to be conducted on lakes Michigan, Erie and Ontario and one-year intensive surveys planned for lakes Huron and Superior (Table 1). The ninth year of the cycle was originally to be devoted to Lake St. Clair (GLWQB, 1976). This nine-year repeating cycle, with intensive open-water sampling limited to one lake a year, was based in part on the assumption that the open waters of the lakes were changing slowly enough to obviate a greater frequency of sampling. Details for specific lake sampling plans were not included in this document.

An intensive survey of Lake Erie followed in 1978–1979, in which responsibility was shared between GLNPO, which conducted a two-year surveillance program to provide a baseline dataset, and the Canada Centre for Inland Waters, National Water Research Institute (CCIW-NWRI), which conducted projects focusing on more specific research questions (Rathke, 1984).

The GLWQA itself was updated in 1978, and included more specific requirements for a surveillance program in the Great Lakes (Annex 11). This called for a joint surveillance and monitoring program to assess compliance with pollution control requirements and achievement of Agreement objects, to evaluate water quality trends and identify emerging problems. The previous plans developed by the GLWQB were to serve as a model for such a program, now referred to as the Great Lakes International Surveillance Plan (GLISP).

A significant change in the 1978 GLWQA was its stated goal "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem," a far broader goal than that of its 1972 predecessor which had focused on the improvement of water quality through pollution control. In addition, the 1978 update set as a goal the 'virtual elimination' of persistent toxic substance discharges. The shift in emphasis in the 1978 GLWQA from a purely water quality viewpoint to an "ecosystem approach" (GLWQB, 1986), as well as the added focus on toxics, posed new challenges in the

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