ARTICLE IN PRESS

JGLR-01350; No. of pages: 4; 4C:

Journal of Great Lakes Research xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Commentary

U.S. EPA Great Lakes National Program Office monitoring of the Laurentian Great Lakes: Insights from 40 years of data collection

Lyubov E. Burlakova[a,*], Elizabeth K. Hinchey[b], Alexander Y. Karatayev[a], Lars G. Rudstam[c]

[a] Great Lakes Center, Buffalo State College, 1300 Elmwood Ave., Buffalo, NY 14222, USA
[b] United States Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, USA
[c] Cornell Biological Field Station, Department of Natural Resources, Cornell University, Bridgeport, NY 13030, USA

ARTICLE INFO

Article history:
Received 29 May 2018
Accepted 29 May 2018
Available online xxxx

Editor: Robert E. Hecky

ABSTRACT

The U.S. EPA Great Lakes National Program Office (GLNPO) implements long-term monitoring programs to assess Great Lakes ecosystem status and trends for many interrelated ecosystem components, including offshore water quality as well as offshore phytoplankton, zooplankton and benthos; chemical contaminants in air, sediments, and predator fish; hypoxia in Lake Erie's central basin; and coastal wetland health. These programs are conducted in fulfillment of Clean Water Act mandates and Great Lakes Water Quality Agreement commitments. This special issue presents findings from GLNPO's Great Lakes Biology Monitoring Program, Great Lakes Water Quality Monitoring Program, Lake Erie Dissolved Oxygen Monitoring Program, Integrated Atmospheric Deposition Network, Great Lakes Fish Monitoring and Surveillance Program, and Great Lakes Sediment Surveillance Program. These GLNPO programs have generated temporal and spatial datasets for all five Great Lakes that form the basis for assessment of the state of these lakes, including trends in nutrients, key biological indicators, and contaminants in air, sediments and fish. These datasets are used by researchers and managers across the Great Lakes basin for investigating physical, chemical and biological drivers of ongoing ecosystem changes; some of these analyses are presented in this special issue, along with discussion of new methods and approaches for monitoring.

Introduction

The U.S. Environmental Protection Agency (U.S. EPA) Great Lakes National Program Office (GLNPO) long-term monitoring programs constitute the longest-running, most extensive monitoring of water quality, lower trophic level biota, and contaminant levels in air, sediments and predator fish across all five Great Lakes by a U.S agency. Data from these surveys have played a major role in tracking shifts in water quality and the lower food web, identification of new non-native aquatic species as well as in identifying changes brought about by these new species. Long-term monitoring provides an opportunity to observe community and ecosystem changes in large lakes and test hypotheses about drivers of change and is especially important when experimental manipulation is not practical, as in the Great Lakes. This special issue presents a collection of findings from up to four decades of GLNPO monitoring programs including the Great Lakes Biology Monitoring Program, Great Lakes Water Quality Monitoring Program, Lake Erie Dissolved Oxygen Monitoring Program, Integrated Atmospheric Deposition Network, Great Lakes Fish Monitoring and Surveillance Program, and the Great Lakes Sediment Surveillance Program. These papers collectively advance our understanding of the Great Lakes ecosystem at the lake-wide and basin-wide scales and aid in tracking the lakes' response to stressors and management actions.

The first paper in this special issue (Barbiero et al., 2018a) provides the historical context for the development of the GLNPO annual Water Quality Survey (WQS) in 1983 and highlights the evolution of the program over the past three decades. The impetus for basin-wide monitoring of the Great Lakes was the 1972 Great Lakes Water Quality Agreement which called for regular monitoring and surveillance to ensure compliance with the goals of the agreement. The resulting Great Lakes International Surveillance Plan (GLISP) specified a nine-year rotation of intensive surveys of the five lakes, based in part on the assumption that the open waters of the lakes changed slowly. Using

* Corresponding author.
E-mail address: burlakle@buffalostate.edu (L.E. Burlakova).

https://doi.org/10.1016/j.jglr.2018.05.017

knowledge gained during the first nine-year cycle of GLISP surveys that documented high inter-annual variability in total phosphorus in the offshore waters, GLNPO initiated an annual WQS in 1983 to track water quality changes and plankton communities in the offshore waters of the lakes. This annual WQS, which supports GLNPO's Great Lakes Biology Monitoring Program and GLNPO's Great Lakes Water Quality Monitoring Program, is unique in that all five lakes are sampled by one agency, using one vessel and one principal laboratory for each parameter group. Thus, data on a uniform set of variables, measured with consistent methodology, are generated by a single agency, allowing cross-lake comparisons to be made with confidence and alleviating the many challenges of combining water-quality data from multiple sources (Sprague et al., 2017).

At its inception, the WQS sampling network was designed to measure conditions in the well-mixed open-lake regions of the lakes where an assumption of spatial homogeneity may be met and the measured variables could be characterized by simple statistics. Lesht et al. (2018) use satellite observations to assess how well statistics based on discrete samples collected during the GLNPO WQS represent the lake-wide values of two variables, surface chlorophyll concentration and Secchi depth. Their findings suggest that the relatively small number of WQS stations in each lake satisfy the goal of representing the state of the offshore open-waters of the lakes. Another application of satellite observations is presented by Warren et al. (2018), who examined the dependence of remotely-sensed chlorophyll concentration on location in the lakes and distance from the shore to test a surface water-based definition of the nearshore zone. The authors found that the width of the nearshore zone is variable, both seasonally and spatially. Although the overall mean and median widths of the nearshore zone closely correspond to the 5 km value used in a number of Great Lakes studies including Lake Michigan, 10% of the estimates were wider (>8.9 km), likely representing times of enhanced mixing and transport of nearshore waters into the offshore.

The GLNPO WQS samples all five Great Lakes twice each year, with a spring survey occurring in March–April and a summer survey in August. Nutrients, traditional water quality variables, phytoplankton, zooplankton, mysids, and benthos are sampled. Barbiero et al. (2018b) use GLNPO's unique dataset to compare the magnitude and timing of changes in lower food web variables from the open waters of Lake Michigan and Lake Huron and offer new insights into drivers of these changes. They show that since the 2000s, both lakes have undergone remarkably synchronous changes in a range of variables, including declines in spring total phosphorus concentrations, dramatic reductions in the size of the spring phytoplankton bloom, increases in water clarity, declines in the abundance of benthic amphipod *Diporeia*, and a biomass reduction and relative shift in summer crustacean communities away from cladocerans and cyclopoid copepods towards calanoid copepods. The major periods of change for these lower food web variables (2003–2005 for Lake Huron, 2004–2006 for Lake Michigan) preceded the main period of dreissenid expansion into the profundal zone in both lakes, and in some cases stabilized while profundal dreissenid populations were expanding. Their calculations of estimated filtration capacity by dreissenids suggest that the primary mechanism driving changes in lower trophic levels was not the direct grazing impacts by offshore dreissenids but rather the shunting of nutrients by nearshore dreissenids (Hecky et al., 2004, Vanderploeg et al., 2010). Also, the synchrony in observed changes in lakes Huron and Michigan indicates a need for further investigation into the influence of broad climatic factors on phosphorus dynamics in these lakes.

The dramatic declines in the benthic amphipod *Diporeia* in all of Great Lakes except Lake Superior prompted a concern that declines in abundances of glacial relict crustacean *Mysis diluviana* may also occur as a consequence of offshore oligotrophication and fish predation switching from *Diporeia* to mysids. Trends in *Mysis* abundance from 2006 to 2016 in all Great Lakes were analyzed by Jude et al. (2018) using the GLNPO dataset. Contrary to the expectations, *Mysis* density and biomass did not decline significantly in any of the lakes, and even increased in Lake Superior, suggesting continued food availability for mysids below the thermocline in these lakes (where mysids occur) and perhaps declines in fish predation. *Mysis* remains a substantial component of the zooplankton community in lakes Ontario, Superior, and Michigan but are less abundant in Lake Huron and rare in Lake Erie.

Seventeen years of the GLNPO Biology Monitoring Program benthic data were analyzed by Burlakova et al. (2018a) to reveal temporal and spatial trends in benthic community structure across the lakes. The authors distinguished the major groups of benthic invertebrates along depth and trophic gradients across the Great Lakes, and identified the major abiotic and biotic factors likely influencing the patterns of distribution, abundance, and species richness of the Great Lakes benthos. Recent decreases in open-lake productivity described in Barbiero et al. (2018a) and elsewhere (e.g., Bunnell et al., 2014; Dove and Chapra, 2015) initiated large changes in profundal communities and resulted in significant shifts in dominant taxa across all lakes except Lake Superior. This sensitivity of benthos to changes in productivity illustrates why benthic invertebrate biomonitoring has long been a tool of choice for assessing the impacts of disturbance in aquatic systems. The Oligochaete Trophic Index (OTI) is one such tool used by GLNPO to assess Great Lakes trophic status (ECCC and EPA, 2017). Burlakova et al. (2018b) used the GLNPO dataset to modify the OTI by expanding the number of oligochaete species used in the index (resulting in an improved OTI, iOTI), adding non-oligochaete species to a new index (resulting in a modified Trophic Index, mTI), and testing a modeling approach using Modern Analogue Technique (MAT) transfer functions based on species responses to a surface chlorophyll gradient. All new indices had a stronger relationship with surface remote-sensed spring chlorophyll than did OTI, and among them MAT models performed the best.

Considering the profound impact of *Dreissena* on invaded ecosystems documented by papers in this special issue and by many other researchers over the past three decades, obtaining precise and reliable estimates of dreissenid populations across both space and time is critical for quantifying their ecological influences via modeling of lake-wide distribution, growth, and filtration rates. *Dreissena* distribution, however, is extremely heterogeneous at all spatial scales, which is a challenge for generating precise estimates of mussel densities. Karatayev et al. (2018a) developed a novel sampling method that analyzes video images recorded using an instrumented benthic sled towed along the lake bed to estimate coverage, density, and biomass of *Dreissena* over large areas (500 m transects) of the lake bed in the Great Lakes. They showed that analysis of images from video transects dramatically increased the amount of bottom area surveyed compared to Ponar grabs and the precision of *Dreissena* density and biomass estimations, thereby improving the ability to detect relatively small changes between years at GLNPO monitoring stations. This method could be a useful and cost-effective addition for monitoring *Dreissena* populations. *Dreissena* monitoring was also found by Karatayev et al. (2018b) to be an effective tool in mapping of the extent and frequency of hypoxia in a large waterbody. Hypoxia occurs seasonally in the bottom waters of some productive basins and embayments in the Great Lakes, including Lake Erie's central basin. These zones are dynamic in time and space, making the spatial and temporal extent of hypoxia difficult to quantify. Using data from the GLNPO Lake Erie Dissolved Oxygen Monitoring Program, Karatayev et al. (2018b) found that persistent summer hypoxia in the central basin results in almost complete elimination of dreissenid mussels at depths >20 m, and that periodic hypoxia may also be an important factor that limits long-term survival of dreissenids in the western basin.

The profound ecosystem changes wrought by dreissenids, notably decrease in turbidity, increase in water clarity, and other physical habitat changes that affect other species in the invaded waterbody, have been well-documented (reviewed by Karatayev et al., 1997, 2015; Higgins and Vander Zanden, 2010). In contrast, there is a paucity of

Please cite this article as: Burlakova, L.E., et al., U.S. EPA Great Lakes National Program Office monitoring of the Laurentian Great Lakes: Insights from 40years of data collection, J. Great Lakes Res. (2018), https://doi.org/10.1016/j.jglr.2018.05.017