Editorial

Mohiuddin Munawar[1] and R. Heath[2],

[1]Research Scientist and Series editor Fisheries and Oceans Canada, Burlington, Ontario, Canada
[2]Professor Kent State University, Kent, Ohio, USA

A traditional Chinese physician begins by checking the pulse of his patient. More than merely determining heart rate, he examines various levels of the pulse and its energy balance between the two sides of the patient. From this quick examination he can estimate the overall health of the patient and make some assessments of where potential problems may lie. So too, this monograph of research on Lake Erie covers a breadth of investigations at various depths. Here we "check the pulse of Lake Erie" in several ways and examine the overall status of the health of the patient: the Lake Erie ecosystem.

This patient was certainly due for a check-up and reappraisal. It's been about a decade since the publication of the State of Lake Erie: SOLE (Munawar et al., 1999) and much seems to have happened to affect the health of Lake Erie. This current assessment, <u>Checking the Pulse of Lake Erie</u>: POLE, is not a routine check-up. We have invited the papers that appear here not merely to provide a general compendium of current work, although this volume does provide that aspect. Instead, the papers that appear here were invited because they address specific topics related to current issues and potential problems that may unfurl in the foreseeable future. Our intent is to provide both a comparison with the research concerns and ecosystems changes since the SOLE was published in 1999, and a view of where those changes appear to lead. This monograph began as an extended Special Session at the Annual Meeting of the International Association of Great Lakes Research held on the campus of DePaul University in Chicago, IL, in June of 2003. Included here are works from well-established research groups, as well as from some of the new investigators in the region. This volume presents reports on the biotic spectrum in Lake Erie, from viruses to fish and birds.

The main stressors on the Lake Erie ecosystem appear to be largely due to human-induced activities: Climate Change, loadings of nutrient and toxic materials, release and introduction of aquatic invasive species. Recent reports indicate that the depth-integrated summer temperature of the lake has increased an average of 0.037 ± 0.01^{o}C per year between 1983 – 2002 (Burns et al., 2005). In this book, Schertzer et al., and Hamblin and Schertzer show that the thermal structure of Lake Erie can be significantly changed in such a way as to reduce duration and extent of ice cover, earlier onset and longer duration of stratification, and possibly a profound change on winter circulation patterns. Indeed, one of the major changes in climate may be an increase in the *variability* of storm events and their effects on the lake. Although the total P load to the lake has remained near or below the target loads (11,000 MT) mandated by the Great Lakes Water Quality Agreement (1978 as amended, 1987), recent loading pulses in 1997 and 1998 give cause for concern (Dolan and McGunagle, 1995). Here, Dolan and Richards report that loadings in these years exceeded target loads not only because of the frequency and duration of storms, but also due to their unusual winter timing. In addition to loading through storm events, the potential for loading from agricultural runoff following irrigation is addressed in this monograph. Loftus and Richards note that irrigation at this time does not lead to significant impacts on Lake Erie water quality, but the amount of ground water that becomes surface water through this activity may become a concern in the future.

The effects of these stressors appear to be far-reaching; indeed it is unclear whether we know the full set of consequences, or even that all consequences of these stressors have yet appeared in Lake Erie. Regular recurrence of increasingly large regions of hypoxia in the central basin, leading to the journalistic hyperbole of “The Dead Zone,” is the most striking of these ecosystem level effects. The causes and consequences of hypoxia in the central basin are not well understood. In the past, regions of hypoxia occurred because of cultural eutrophication that resulted in excessive growth of poorly grazed phytoplankton, largely cyanobacteria, which in turn died, descended to the bottom waters, and decayed, with consequent consumption of hypolimnetic oxygen by heterotrophic bacterial activities. The current regions of hypoxia are not caused in the same way. Here it is shown that total P-loadings are at or below GLWQA target loads (Dolan and Richards), phytoplankton communities in the central basin do not appear to be dominated by “eutrophic species” (Munawar, M. et al.; Meilander et al.), and phytoplankton in the bottom waters remain alive and potentially active (Munawar et al.). Whether hypoxia of the central basin in Lake Erie is “caused” by some errant input, or by some other oxygen consumptive process, such as nitrification of ammonium externally loaded from agricultural activities or internally loaded by dreissenid excretion, or is merely a consequence of global climate change (Schertzer et al.) remains to be seen.

The consequences of large zones of hypoxia are not fully understood, and very little attention has been directed to understanding these consequences, especially at the ecosystem level. It is reasonable to expect releases of phosphate in the bottom waters, but releases of certain species of various metal ions can also occur. Especially Fe has been noted to be a factor limiting phytoplankton productivity in the central basin in the summer, but to vary seasonally (Porta et al., 2005). As Twiss indicates here, very little attention has been given to ionic speciation in Lake Erie and to those conditions that may affect ionic oxidation and reduction. This is an important issue, inasmuch as phytoplankton can respond differently to various oxidation states of the same ion, and that response is as likely to be stimulatory as inhibitory (Twiss et al. 2005). Regions of hypoxia can also perturb nutrient availability. N and S cycles both depend on redox potential of the surrounding waters, and P indirectly is controlled by redox potential, via Fe redox. Regions of hypoxia can result in release of large amounts of P and could also lead to great decreases in N through increases in the rate of dissimilatory denitrophication, as nitrate is transformed to N_2O and molecular nitrogen, conceivably altering the availability and relative abundance of these critical nutrients.

The status of plankton and benthic communities in Lake Erie appears to be changing, and in many respects to be declining. Phytoplankton species diversity was high across the lake (Munawar et al. this volume) dominated by nanoplankton (2-20um). In general, phytoplankton communities in Lake Erie are not as strongly P-limited as they once were (Lean, et al. 1983, Guildford et al. 2005, Meilander et al., this volume), as shown by comparison of physiological indicators (alkaline phosphatase, P-debt, phosphate turnover rate, and C:N:P stoichiometry). It is likely that factors other than P-loading alone affect phytoplankton growth and diversity. In this volume the role that planktonic bacterial viruses may play in recycling P is presented (Dean et al.). Also, in this volume appears support for the view that P-availability to phytoplankton is controlled by bacterioplankton abundance and phosphate assimilation rate (Gao and Heath, 2005; Meilander and Heath, this volume).

The western basin appears to be more eutrophic than it was a decade ago (Conroy et al., this volume), and the fraction of inedible cyanobacteria appears to be on the rise in the western basin. In this volume is presented a novel Plankton Index of Biotic Integrity (P-IBI), based on numerous metrics of phytoplankton and zooplankton structures. The P-IBI indicates an increase in Lake Erie water quality from the 1970s to 1995 but that it declined from mid-1990s through 2002 (Kane et al.). The gradual decline of water quality and increased presence of cyanobacteria in Maumee Bay from 1978 to the present are noted by Moorhead et al. The benthic communities of the lake present a mixed picture of ecosystem health. The appearance of burrowing mayflies (*Hexagenia*) in the western basin is an indication of improving benthic community health (Edsall et al., 2005). In contrast, the ubiquity of dreissenid mussels in all basins (Dermott, this volume), the decline of gammarid amphipods, and the near extirpation of the amphipod *Diporeia* are cause for great concern. The decline in amphipod distribution and abundance are unclear, but often it is felt that they have been unable to compete with the dreissenid mussels for food.

Of course, one of the major concerns in Lake Erie for the past several decades has been the introductions of numerous non-indigenous species. The most notable introduction was that of the dresissenid mussels. During the past decade *Dreissena polymorpha* (zebra mussel) has been largely displaced by its congener, the quagga mussel (*D. bugensis*); the causes of this displacement are unclear, and its consequences are virtually unstudied (Patterson et al., 2005; Dermott, this volume). Here we review the entire set of introductions of non-indigenous species (NIS) to Lake Erie (Bailey et al.; Zhu et al.). The introductions of NIS are a rate of about one species per year, largely via ship ballast water. It is unlikely that much headway toward preventing such introductions will be made until the pathways of introduction are blocked, most likely by appropriate legislation.

Based on 20 manuscripts the monograph provides a holistic treatment of the Lake Erie ecosystem covering a variety of topics. Various papers have been grouped in to three sections namely: Physical regime; Biological regime and Current issues. These papers as indicated above provide an integrated and top down picture of the status of the health of the patient under check up-Lake Erie.

We are grateful to the Aquatic Ecosystem and Management Society (AEHMS) for their efforts, encouragement and funding towards the organization of the symposium and publication of this monograph. We would like to thank the International Association of Great Lakes Research (IAGLR) for their support in convening of the symposium as part of the Chicago conference. We greatly appreciate the support and assistance of Iftekhar. F. Munawar, managing editor of the series, for her interest and assistance in the project. Thanks are also due to Nabila Munawar and Ahmad Munawar for technical editing; Susan Blunt and Jennifer Lorimer for copy editing/coordination, Joanne Dziuba for the cover design and Bev Weiler for the preparation of the index. We greatly appreciate the contribution of the foreword by Drs. Joe Leach and Ed Mills, who have tremendous experience and insight about the dynamics of the changing Lake Erie ecosystem. We hope that this monograph will provide the current and integrated assessment of the health of Lake Erie ecosystem, and serve its role in providing in-depth information and data to students, researchers, managers and policy makers interested in the conservation and protection of Lake Erie.