Lake Erie at the Millennium Conference (1999)

Trends, Trajectories, and Changes – A Binational Conference

April 26-28, 1999, University of Windsor, Windsor, Ontario

This document is an abstract digest of the presentations made during the 1999 Lake Erie at the Millennium conference. The conference was the first in a regular series of binational conferences, co-convened by the University of Windsor Great Lakes Institute for Environmental Research, the National Water Research Institute, the Ohio Sea Grant - F.T. Stone Laboratory of Ohio State University, and the Large Lakes Research Station, US EPA of Grosse Ile.

For more information on the LEMN conference and workshop series, please visit the Lake Erie Millennium Network website: http://www.lemn.org

Session I. Physical Structure of Lake Erie

Lake Erie Geology and Landforms: Overview, Issues and Forecasts.

C.E Herdendorf (Herdendorf@aol.com) Dept. of Geological Sciences, The Ohio State University, Columbus, OH.

The bedrock formations in the Lake Erie region contain important industrial and energy minerals, including limestone, sandstone, clay shale, gypsum, halite (rock salt), natural gas, and oil, whereas the unconsolidated glacial and lacustrine beds yield clay, peat, sand, gravel, groundwater, and fertile soils. However because most of the bedrock in the Lake Erie basin is blanketed by these glacial deposits, the lithology and structure of the underlying rock has not been determined. Also, the extraction and processing of economic mineral deposits often involves land use conflicts. Another important issue is coping with geological hazards including, earthquakes as resultant soil liquefaction (magnitude 6 tremor near Ashtabula in 1998), sinkholes and caves associated with karst (limestone) terrains, abandoned mine subsidence, shoreline erosion and bluff recession, radon and other toxic gases, landslides and mass wasting, springs and groundwater seeps, lake/tributary flooding and storm surges, and swelling soils. The water level history of Lake Erie and related crustal rebound processes are imperfectly understood which has lead to confusion and conflicting predictions of lake level trends. Finally, the integral relationship between geology and sustainable biotic habitats is often not given appropriate consideration when construction projects are proposed. Several of the states surrounding the Lake Erie drainage basin are embarking on a long-range mapping program designed to produce three-dimensional, computer-based maps of the lake basin. These will include geologic materials from soil to bedrock, resources from water to construction aggregates, processes from erosion to earthquakes, and systems from natural to managed watersheds. Surficial geologic maps of this type will facilitate emerging concepts such as "smart growth," "sustainable development," "brownfield redevelopment," and "greenfield preservation." To deal with the complexities of the coastal region, shoreline classification systems based on geological origin and contemporary processes will need to be developed. Students in the geological sciences will need to be encouraged to undertake detailed mapping projects, utilizing emerging technologies, and be given academic rewards for selecting this line of research.

Lake Erie Sedimentation and Sediment Distribution.

Scudder D. Mackey (sdmackey@lrbeg.com) and J.A. Fuller. US Geological Survey Great Lakes Center, 1634 Sycamore Line, Sandusky, OH.

Numerous studies collected sediment distribution data from open lake and nearshore zones of Lake Erie. The earliest regional data were collected in the 1870's during the U.S. Lake Survey of the Great Lakes. Subsequent studies utilized various; sampling devices and shallow cores to sample the bed of Lake Erie. Many site specific and regional maps were published illustrating sample locations and surface sediment distributions. Cores, jetted holes, and geophysical (seismic) tools were used to probe the sediments below the bed of Lake Erie. More recently, geophysical tools such as sidescan and swath sonar were integrated with GPS (Global Positioning Systems) and GIS (Geographic Information Systems) to more accurately map surface sediment distributions on the bed of Lake Erie. Subsurface data show that bedrock, glacial and glacio-lacustrine, and more recent lacustrine sediments partially fill the Lake Erie Basin. In general, fine-grained sediments (clay and silt) are distributed in deep-water areas of Lake Erie. Coarse-grained sediments (sand and gravel) are distributed in nearshore zones within 650 meters of the shoreline in water depths less than 10 meters. Coarse-grained sediments are also associated with several relict cross-lake morainal deposits in the Central and Eastern basins of Lake Erie. The most pronounced changes in sediment distribution are occurring in nearshore zones where shoreline armoring and dam construction impact sediment source areas that supply coarse-grained sediments to Lake Erie beaches. The reduction in sediment supply has reduced the width and thickness of beaches, accelerated coastal erosion and downcutting in the nearshore zone, and eliminated many of the coastal barriers that \protected Lake Erie's coastal marshes and wetlands. Moreover, zebra mussels (Dreissena polymorpha) in the nearshore zone have changed the character of Lake Erie beaches and are spreading rapidly across soft substrates in the Western Basin and shallow-water areas of the Central Basin of Lake Erie. The potential socio-economic and ecosystem impacts of these changes in sediment distribution have not been evaluated.

Coastal Processes and Erosion on Lake Erie at the Millennium.

Rob Nairn (rnairn@baird.com) and P.J. Zuzek. Baird & Associates 627 Lyons Lane, Suite 200, Oakville, ON L6J 5Z7.

The shore of Lake Erie has been evolving in response to wave action at or near the present lake level for several thousand years. These processes have created eroding bluffs in areas of high relief and sandy depositional features in other areas. In the last 20 years there have been tremendous advances in our understanding of the processes that are responsible for the ongoing evolution of the shoreline. Pioneering research efforts on Lake Erie in the early 1980's were the key to a new understanding of erosion processes for shorelines formed in glacial sediments - referred to as cohesive shores. Cohesive shores usually feature an eroding bluff or cliff at the shoreline and the knowledge developed from these Lake Erie investigations is now applied to similar shorelines throughout the world. In the early 1990's the entire length of the Lake Erie shoreline was classified on a 1 km reach basis through a three-tier system (above water geomorphic, underwater geology and shore protection) as part of the International Joint Commission Levels Reference Study. Very recently the shoreline classification system has been revised and refined for the entire US shore of Lake Erie as part of the Lower Great Lakes Erosion Study (LGLES) sponsored by the Buffalo District Corps of Engineers (COE). Over the next two to three years it is planned that a Flood and Erosion Prediction System (FEPS) will be implemented for the entire US shoreline of Lake Erie under the LGLES utilizing the shoreline classification system. Baird & Associates have recently developed and implemented the FEPS for the entire shoreline of Lake Michigan for the Detroit District COE. The ArcView GIS based FEPS will provide a versatile Coastal Zone Management tool for managing and accessing physical coastal data and for predicting waves, water levels, nearshore coastal processes, erosion and deposition under existing conditions and future "what if" scenarios.

Mapping and Monitoring Wetland Ecosystem Health Using High-Resolution Casi Imagery.

Marilynne Jollineau(1) (myjollin@fes.uwaterloo.ca), L. Maynard(2), G. McCullough(2), and P. Howarth(1). 1.University of Waterloo, Department of Geography, Waterloo, ON; 2.Canadian Wildlife Service, Environment Canada.

Wetlands within the Lake Erie basin are among the most productive, life-supporting ecosystems in this region of North America. They provide habitat for fish, wildlife and waterfowl; hydrological benefits by regulating water levels; water quality protection and several economic benefits through recreation and tourism (Wetzel, 1992; Klemas et al., 1993). Human activities within these environments, however, have led to the disappearance of as much as 70% of the pre-settlement wetland area (Krieger et al., 1992; Mitsch, 1992). The Lake Erie basin has one of the highest rates of long-term wetland loss in Canada. Land use within this basin has also severely affected the quality and quantity of wetland vegetation within this region. Loss of both inland and coastal wetlands has occurred, to a large extent, from the conversion of wetlands by draining them for intensive agriculture and, to a lesser extent, by infilling them for commercial and/or residential development (Snell, 1987; Mitsch and Gosselink, 1993). As a result, a range of methods have been developed in order to accurately monitor and assess remaining wetlands, in terms of their status and health. Remote sensing techniques provide powerful tools that can be used to map, monitor and assess the remaining Lake Erie wetlands. Traditional methods of collecting wetland data have included the use of aerial photographs and detailed ground surveys. Improvements in remote sensing, however, provide many advantages over traditional methods including timely data collection with lower costs over time, data in a digital format, a standardized data-collection procedure and an opportunity for data integration within a geographical information system (Cihlar, 1996; MacDonald, Dettwiler and Associates, 1998). Recent advances in remote sensing have provided an opportunity to acquire detailed information about wetland environments including precise x, y location, the shape and size of wetland areas, wetland vegetation types/classes (at the community and species level), vegetation extent and distribution, land use, wildlife habitat classes and water quality through the use of high-spatial and high-spectral (or "hyperspectral") resolution imaging spectrometers (Consulting and Audit Canada, 1994; Jollineau, 1997; MacDonald, Dettwiler and Associates, 1998). Current research activities are evaluating imaging spectrometers (e.g. the Compact Airborne Spectrographic Imager or casi) to determine the extent to which these instruments can be used to meet the operational wetland mapping and monitoring requirements of a variety of government and non-government agencies including the Canadian Wildlife Service, Ducks Unlimited Canada, and other federal and provincial government agencies responsible for wetland conservation. Of special interest in this context is the use of casi imagery to monitor and assess wetland ecosystem health.

Trends in Agricultural Land Use Practices Southwest Ontario.

Peter Roberts (proberts@omafra.gov.on.ca). Ministry of Agriculture, Food and Rural Affairs, 1 Stone Rd. W., Guelph, ON.

Agricultural land use practices have a significant role to play in the non-point source contamination of water courses. Initiatives and adoption of management practices being adopted by Ontario farmers fit with the goals and objectives regarding reduction of nonpoint sources of pollution from land use practices that are expressed in the Great Lakes Water Quality Agreement. The scope of this paper illustrates trends in land use practices adopted by Southwestern Ontario farmers. Empirical research and census data over the last decade and a half has shown that farmers have been adopting conservation farming systems such as crop residue management, conservation tillage and improved fertilizer management practices. Recent farmer involvement in initiatives such as the Environmental Farm Plan, Best Management Practices and Nutrient Management Planning are enabling agricultural operations throughout Ontario to become more environmentally responsible. Emerging environmental challenges facing producers will also be discussed

Physical Structure and Impacts on Lake Erie Ecosystem: Challenges for the Future.

Scudder D. Mackey(1) (sdmackey@lrbeg.com), and C. E. Herdendorf(2). 1.US Geological Survey Great Lakes Center, 1634 Sycamore Line, Sandusky, OH. 2. The Ohio State University, 1507 Cleveland Rd. E. #410, Huron, OH.

Numerous studies collected sediment distribution data from open lake and nearshore zones of Lake Erie. The earliest regional data were collected in the 1870's during the U.S. Lake Survey of the Great Lakes. Subsequent studies utilized various; sampling devices and shallow cores to sample the bed of Lake Erie. Many site specific and regional maps were published illustrating sample locations and surface sediment distributions. Cores, jetted holes, and geophysical (seismic) tools were used to probe the sediments below the bed of Lake Erie. More recently, geophysical tools such as sidescan and swath sonar were integrated with GPS (Global Positioning Systems) and GIS (Geographic Information Systems) to more accurately map surface sediment distributions on the bed of Lake Erie. Subsurface data show that bedrock, glacial and glacio-lacustrine, and more recent lacustrine sediments partially fill the Lake Erie Basin. In general, fine-grained sediments (clay and silt) are distributed in deep-water areas of Lake Erie. Coarse-grained sediments (sand and gravel) are distributed in nearshore zones within 650 meters of the shoreline in water depths less than 10 meters. Coarse-grained sediments are also associated with several relict cross-lake morainal deposits in the Central and Eastern basins of Lake Erie. The most pronounced changes in sediment distribution are occurring in nearshore zones where shoreline armoring and dam construction impact sediment source areas that supply coarse-grained sediments to Lake Erie beaches. The reduction in sediment supply has reduced the width and thickness of beaches, accelerated coastal erosion and downcutting in the nearshore zone, and eliminated many of the coastal barriers that \protected Lake Erie's coastal marshes and wetlands. Moreover, zebra mussels (Dreissena polymorpha) in the nearshore zone have changed the character of Lake Erie beaches and are spreading rapidly across soft substrates in the Western Basin and shallow-water areas of the Central Basin of Lake Erie. The potential socio-economic and ecosystem impacts of these changes in sediment distribution have not been evaluated.

Session II. Lake Erie Loadings and Flux

Rural Loadings: An Ohio Perspective.

R. Peter Richards (prichard@heidelberg.edu) and D.B. Baker. Water Quality Laboratory, Heidelberg College, 310 E. Market Street, Tiffin OH.

Over the last 20 years, total phosphorus loadings have decreased by 30 to 40% in the Maumee and Sandusky watersheds, and soluble phosphorus loadings have decreased by approximately 75%, mostly due to increased conservation tillage and reduced fertilizer/manure applications. A by-product of increased conservation tillage has been a reduction in sediment loadings by about 20%. Nitrate concentrations have probably increased somewhat, but the trend is not statistically. The trajectory for the next few years is uncertain, and will remain so after the fact, due to the very large annual fluctuations imposed by variations in weather. Ex-Voinovich called for a 67% reduction in sediment loads to encourage the return of aquatic macrophytes in the lower reaches of the tributaries. The western half of the Ohio Lake Erie basin may be the site of a major Conservation Reserve Enhancement Program designed to reduce sediment losses to the tributary system. Reduced sediment implies reduced phosphorus. On the other hand, some farmers are becoming discouraged with conservation tillage and reductions in acreages in conservation tillage may result. Nitrate will remain relatively unmanaged, despite hypoxia in the Gulf of Mexico and elsewhere. Relationships between conservation tillage and nitrogen export are inconsistent. Conversion of ammonia to nitrate at sewage treatment plants implies increasing nitrate loads. Suburban sprawl is likely to continue shifting the land use distribtion in the Lake Erie basin, but the implications for loadings are ambiguous. Three major factors hinder this forecast: weather-induced variability, lack of understanding of delivery of materials from the monitoring point to the open lake, and the inadequacy of current monitoring efforts in most of the Lake Erie basin.

PCB and Dioxin/Furan Cycling in an Urban Environment: A Conceptual Analysis.

Edwin Tam(1) (edwin.tam@utoronto.ca). M. Diamond(2) and S. Painter(3). 1. Department of Geography, University of Toronto, Toronto, ON; 2. Department of Geography, Department of Chemical Engineering, University of Toronto, Toronto, ON; 3. Regional Studies Section, Environmental Conservation Branch, Ontario Region, Environment Canada, Burlington, ON.

No abstract available

Research and Monitoring Issues for Sources of Urban Pollutants in the Lake Erie Watershed.

David M. Dolan (doland@uwgb.edu) and K.P. McGunagle. University of Wisconsin at Green Bay, Natural and Applied Sciences ES-317, 2420 Nicolet Drive, Green Bay, WI.

Since the mid-1970's, point sources of phosphorus in the Lake Erie watershed have been tracked by governments charged with meeting target loadings set forth in the Great Lakes Water Quality Agreement. The result has been not only significant improvements in Lake Erie water quality, but a database that can be utilized to answer a variety of management questions. As wastewater treatment came on line, the importance of non point reductions, detergent phosphorus bans and tighter effluent limits could all be evaluated. Efforts to evaluate the significance of point source loadings of other pollutants within the watershed, especially trace metals and organic compounds, have not met with as much success. Monitoring for chemicals such as mercury and PCBs is much more expensive than for phosphorus and requires more quality assurance to yield results that can be used for load estimation. Resultant data are frequently censored, i.e. some or all of the values are below

detection limits. Special load computation methods such as maximum likelihood estimation (MLE) are often required. Several relatively insignificant sources of phosphorus pollution have the potential to be important sources of other pollutants. Rapid, reliable monitoring of groundwater-surface water exchange near landfills is needed. Urban air deposition, especially due to precipitation, is significantly elevated with respect to samples collected at the IADN sites. A method to account for these differences in atmospheric load estimates is needed. Combined sewer overflows present special challenges for obtaining representative estimates of quantity and quality to evaluate the significance of inputs from these sources.

Biogeochemistry of Trace Metals in the Water Column of Lake Erie.

Michael R. Twiss (m2twiss@acs.ryerson.ca). Ryerson Polytechnic University Department of Applied Chemical and Biological Sciences, 350 Victoria Street, Toronto, ON.

No abstract available

Temporal Trends and Current Metal Loadings in Surficial Sediments of Western Lake Erie.

Brian Fryer bfryer@uwindsor.ca, A. Toms, J.C. Barette, and A. Grgicak, Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON.

No abstract available

Distribution of Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons in the Food Web of Western Lake Erie.

Sarah Gewurtz(gewurtz@uwindsor.ca) and G.D. Haffner. Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON.

Two important classes of contaminants in western Lake Erie are polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). The exposure dynamics of PCBs have been well studied because high levels are often detected in top predators, and because coplanar PCB congeners are known to be highly toxic to aquatic organisms. PAHs have not been emphasized because they are metabolized by higher organisms and thus not detected by conventional monitoring programs. However, recent evidence has shown that PAH metabolites may be responsible for elevated tumor occurrences in benthic fish species though the chemical stress to other organisms is not well known. In 1998, sediment, plankton, and benthic invertebrates were collected from western Lake Erie and analyzed for 39 PCB and 17 PAH congeners. Concentrations of SPCBs in zebra mussels, amphipods, crayfish, and plankton were 7.93, 7.83, 7.31, and 0.035 ug/g lipid respectively. SPAHs were 6.2, 2.5, 0.71, and 0.0079 ug/g lipid respectively. If chemicals are in thermodynamic equilibrium, the biota-sediment fugacity ratios for each species should equal 1. The results indicate that equilibrium dynamics are not occurring. Fugacity ratios for PCBs follow a parabolic relationship with Kow whereas fugacity ratios for PAHs are inversely related to Kow. For benthic invertebrates, PCB fugacity ratios range from 0.15 to 4.58 and PAH fugacity ratios range from 0.0056 to 2.1. The results demonstrate that the exposure dynamics of PCBs and PAHs are different and that future research on the risk of chemicals in aquatic ecosystems should include both persistent and non-persistent chemicals.

Deposition of Airborne Toxic Substances to Lake Erie.

William M. J. Strachan (william.strachan@cciw.ca). National Water Research Institute Environment Canada, Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington ON.

The Great Lakes Water Quality Agreement includes Annex 15, which requires Canada and the United States to operate a network of atmospheric sampling sites within the basin. The purpose is to provide data to assess the atmospheric loadings of toxic chemicals to the lakes. The Lake Erie station is at Sturgeon Point, 40 km southwest of Buffalo, NY. Air samples have been collected there since 1992 (1:12 d) along with wet deposition (rain/snow, 4 week cycle). Some 20 organochlorine pesticides and nearly 100 PCB congenors are determined. An early mass balance assessment for Lake Erie with pre-1986 data indicated that wet plus dry deposition loadings of PCBs and DDT were 182 and 33 kg/year, respectively; the vapour phase contribution was a net loss from the lake of 1100 and 213 kg. Data quality at the time was debatable. More recent estimates place total deposition at 58 and 71 kg with the volatilization of PCBs at 390 kg and absorption of DDT at 39 kg. These two analytes are presented here only as representational of the data although earlier databases are weak. These loadings will be discussed in the context of the total loadings to the lake and compared with other Great Lakes for which the data bases are more complete.

Development of an Ecosystem Model for Integrated Management of Nutrients and PCBs in Lake Erie.

Joseph V. DePinto(1) (jdepinto@limno.com), V.J. Bierman(2), T.J. Feist(2) and J. Kaur(1). 1. Great Lakes Program, State University of New York at Buffalo, Dept of Civil, Structural and Environmental Engineering, 202 Jarvis Hall, Buffalo, N.Y. 2. Limno-Tech, Inc., 501 Avis Drive, Ann Arbor, MI.

Historically, mathematical modeling of aquatic resources within the Great Lakes has focused on assessment and evaluation of management strategies for individual management issues (e.g., eutrophication, fisheries, toxic chemical exposure). With the advent of the "Ecosystem Approach" for governing and managing the Great Lakes, we have begun to observe and recognize that actions directed toward one management area can impact other problem areas. This realization has led us to a vision for the next generation of aquatic resource models, which incorporates these ecosystem linkages by coupling models of heretofore separate issues. In this paper we will present the conceptual framework for this ecosystem model. The conceptual model contains biotic and abiotic components that are necessary to investigate some of the important ecosystem linkages between nutrient dynamics, phytoplankton functional groups, zooplankton, benthic populations (including zebra mussels), forage fish, sport fish, and bioaccumulative chemicals of concern (such as PCBs). Progress toward this vision is exemplified by results of three ongoing aquatic ecosystem modeling projects: investigation of the effect of nutrient loadings and zebra mussel functioning on phytoplankton dynamics in Saginaw Bay; appplication of a screening-level model of the potential impact of zebra mussels in Lake Erie on cycling and potential bioaccumulation of PCBs; and conceptualization of a Lake Michigan Ecosystem Model as part of the Lake Michigan Mass Balance Study. Additional model development, process research and field data acquisition is needed in many areas. Some broad areas for research include: fish bioenergetics and population dynamics and coupling with lower food web; benthic production and coupling with pelagic food web; dynamic effects of trophic structure and function on contaminant bioaccumulation; and zebra mussel population dynamics and processing of nutrients and contaminants. Also, a large integrated field program that includes measurement of nutrient and contaminant loads, all important state variables, and process rates where possible is necessary to calibrate our ecosystem model.

Session III. Environmental Features and Climate Variability and Change: Implications for the Lake Erie Basin.

Climate Variability and Change: Implications for the Lake Erie Basin.

Linda Mortsch (linda.mortsch@ec.gc.ca). Environmental Adaptation Research Group, Environment Canada, c/o Faculty of Environmental Studies, University of Waterloo, Waterloo, ON.

Climate change due to an "enhanced greenhouse effect" is gaining recognition as a serious environmental issue. The Intergovernmental Panel on Climate Change (IPCC) has stated that there is "a discernable human influence on the climate system". Climate change is potentially an additional stress on the Lake Erie ecosystem that must be incorporated into research, programs and management of the system. Historical trends in temperature and precipitation as well as water level changes will be summarized. For example, the year 1998 was the warmest and 5th driest year on record for the Great Lakes ecoregion. Temperature and precipitation scenarios of climate change from selected climate models (transient and equilibrium experiments) will be presented. Analysis of these scenarios suggest that climate change has implications for soil moisture, runoff, water levels, water temperatures, buoyancy driven turnover and water quality.

A Current Perspective on Lake Erie Water Level Fluctuations.

Frank H. Quinn (quinn@glerl.noaa.gov) Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan Great Lakes Environmental Research Laboratory, NOAA, 2205 Commonwealth Blvd., Ann Arbor, MI

No abstract available

Lake Erie Thermal Structure.

William M. Schertzer William.Schertzer@cciw.ca and P.F. Hamblin. National Water Research Institute, 867 Lakeshore Rd., Burlington, ON.

Water temperature is a fundamental variable in the study of large lakes, having implications on the physical, chemical and biological components as well as water quality and socio-economic considerations. In Lake Erie, there has been an accumulated wealth of temperature data from the 1960's to the present based on lake surveys, in situ measurements, airborne infrared radiometer techniques and satellite observations. These data allow description of important features of the lake-wide and basin-wide thermal structure characteristics. We describe principal features of the thermal structure focusing on the long-term temperature and heat storage characteristics resulting from radiative and turbulent heat exchanges at the air-water interface and primary characteristics of the annual thermal cycle including advance of the spring thermal bar, variability of the thermocline position and time of overturn. The long-term data record clearly demonstrates that there are years with a lack of data representativeness both spatially and temporally. Such problems make it difficult to rely on the observational record alone for analysis of temperature related issues (e.g., water quality simulations, El Nino responses, etc.), necessitating the development and application of a hierarchy of thermal models for simulating / forecasting lake temperature fields. An important application of thermal models has been in assessing potential lake responses to climate warming. Due to the shallowness of Lake Erie, it's thermal structure is more susceptible to short-term changes in climate compared to the other Laurentian Great Lakes. Preliminary research combining thermal models with climate warming scenarios (e.g., Global Circulation Model scenarios) have indicated that the thermal structure of Lake Erie can be significantly changed which has implications for other ecosystem components and water quality. We use the observational record and thermal model results to

indicate the current status of the lake thermal structure, potential responses to climate warming and critical areas for future research.

Past, Present and Future of Solar Radiation in Lake Erie.

Ralph E.H. Smith(1) (rsmith@sciborg.uwaterloo.ca), B.M. Greenberg(1), C. Marwood1,V.P. Hiriart(1), and M.N. Charlton(2). 1. Biology Department, University of Waterloo, Waterloo, ON and 2. Environment Canada, N.W.R.I., C.C.I.W., Burlington, ON.

Control of nutrient loads and colonization by Dreissena sp. are thought to have increased the transparency of Lake Erie to solar radiation, and continued expansion of Dreissena sp. into deeper waters may continue the trend to clearer water. Surface-incident ultraviolet-B radiation (280-320 nm) meanwhile continues to increase as stratospheric ozone concentrations decline. Greater water clarity may expand the photic zone of the lake but also increase the UV exposure of aquatic organisms. Forecasting the consequences for the lake depends on a good understanding of the factors controlling spectral transmission. We present evidence that the effects of Dreissena sp. on water clarity cannot be explained solely by their removal of phytoplankton, and that water column chlorophyll a concentration is a relatively minor influence of visible and ultraviolet radiation attenuation in Lake Erie. Consistent with this reality, transparency in some parts of the lake has deteriorated again in recent years even though chlorophyll a concentrations remain lower than in pre-Dreissena years. The role of Dreissena in facilitating sedimentation of non-phytoplankton particles, the fate of the sedimented material, and changes in the nature and extent of sediment re-suspension are likely to be key factors in the biological control of water clarity. Uncoupling of water transparency and UV transmission from phytoplankton abundance has significant implications for predictions of water clarity, UV exposure, and primary production in future years.

Lake Erie Water Quality in the 90s: A Time of Transition.

Murray N. Charlton (murray.charlton@cciw.ca) National Water Research Institute, Environment Canada, P.O. Box 5050, Burlington, ON.

Lake Erie began to recover from excessive nutrient loads and the near extirpation of the Walleye in the 1970s. In the mid-1980s nutrient loads had been reduced by half and there had been an explosion of the Walleye population. By the late 1980s, the nutrient load goals had been attained but an increasing number of exotic species such as Bythotrephes sp. and Dreissena sp. began to appear and these have changed the system forever. By the 1990s the Walleye explosion had subsided and the population resumed its former upward trajectory. In the late 1990s there has been pressure by some fishing interests to increase nutrients loads in order to increase fish yields and this raises the question of the long term controls on algae and the effects of nutrient controls and exotic species mainly Dreissena sp. Data for the offshore areas was examined. Phosphorus declined by 20 ugP/l in the west basin and by about 3 ugP/l in the central and east basin before the mussel invasion. Most of the productivity decrease or chlorophyll decrease occurred due to the nutrient controls prior to the mussels. Mussels seem responsible for a loss of about 20% of the remainder. Secchi transparency offshore changed little post-mussels. The effect of the mussels on the offshore seems variable or, at least, is still evolving. Losses of phosphorus in 1994 to 1995 (unprecedented low) were largely recouped in 1996 and 1997. There seem to be new processes operating that affect the offshore and, by inference, the majority of the lake area as well as the nearshore area that should be even more intensely affected. This seems to be a time of transition from the old Lake Erie paradigm towards a new paradigm which is slowly developing as more and more exotic species appear. For this reason no fundamental change in nutrient policy is advocated.

Session IV. Open-Water Biotic Processes

Probing the Microbial Food Web of Lake Erie: Status and Changes.

Mohi Munawar (munawarm@dfo-mpo.gc.ca), I.F. Munawar, H. Van Stam and M. Fitzpatrick. Department of Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, ON.

Not much is known about the microbial food web structure and interactions in Lake Erie with the exception of phytoplankton which is well established. Fisheries and Oceans Canada has maintained a long term and lakewide database of Lake Erie phytoplankton and primary productivity since the early 1970's which permitted the assessment of the impact of the invasion of zebra mussels. Generally a shift from Diatoms to Green Algae was apparent. An overview of the carbon-14 size fractionated primary productivity data revealed that small sized organisms such as autotrophic picoplankton (20µm) contributed the least to productivity, especially in the eastern basin. Significant structural and functional differences were observed for the three basins. Although the microbial loop and its function is well established in marine ecosystems, little is known about the microbial plankton of the Great Lakes in general and Lake Erie in particular. Microbial surveys were initiated in Lake Erie on a lakewide basis in 1992, continued during 93-94 as a part of the Lake Erie trophic transfer (LETT). Microbial parameters such as bacteria, autotrophic picoplankton, heterotrophic nanoflagetllates and ciliates were evaluated across the lake by means of epifluorescence-DAPI and quantitative Protargal Staining (QPS) techniques. In conjunction with the phytoplankton analysis by the standard Uthermohl technique, carbon-14 size fractionated primary productivity experiments were also conducted. These surveys have provided insight into the microbial foodweb structure of Lake Erie for the first time. The availability of this new microbial data has opened new frontiers of research and modelling in enhancing our understanding of the microbial food web dynamics and its linkage to fisheries about which very little is known.

Changes in Phytoplankton Productivity in Lake Erie.

E. Scott Millard (millards@dfo-mpo.gc.ca) and M.S. Burley. Great Lakes Lab for Fisheries & Aquatic Science, Department Fisheries & Oceans, Burlington, ON

Phytoplankton productivity has undergone significant declines since the early 1970's due to the combined impacts of phoshphorus control and more recently, zebra mussel invasion. Seasonal rates of areal phytoplankton photosynthesis have declined by as much as 50% in the west and 75% in the east basin. Whole-lake carbon fixation in Lake Erie may now be about equal to Lake Ontario in spite of 30% larger surface area. Consistent application of 14C-incubator methodology has led to development of a valuable database across three ecosystems, Lake Ontario, Bay of Quinte, and Lake Erie. This has led to development of relationships such as chlorophyll and seasonal photosynthesis vs. phosphorus than help asses the performance of the phytoplankton community. Presently, the nearshore east basin is well below the productivity potential set by phosphorus levels while other parts of the lake may not be as impaired. Seasonal (east basin 1998) and lakewide measurements of phosphorus demand and turnover times have also been made.

Lake Erie Phytoplankton at the Millennium: Nutrients, Zebra Mussels, and the Future.

David A. Culver, (culver.3@osu.edu), Li Hui, and Lisa Babcock-Jackson. Dept. Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, OH

Trends: Since 1970, decreased phosphorus and increased nitrogen input have affected the functioning of the Lake Erie pelagic ecosystem (including algal, zooplankton, and fish abundances), even before the introduction of dreissenids further altered biological balances in the lake. May-August mean algal biomass (mg wet weight/l) in the western basin declined from 5.3 (1970) to 2.0 (1985) to 0.9 (1995-97). Comparable data for the central and eastern basins were (3.1, 1.0, 0.7) and (2.3, 0.4, 0.4), respectively. Current Status: The cyanophyte blooms that were so common in the 1970s have abated, with Chrysophyta and Cryptophyta dominating in 1996-97 in the western basin (67% and 21%, respectively). Central basin algae were dominated by Chrysophyta (55%), Cryptophyta (24%), and Pyrrhophyta (10%). Nevertheless, major blooms of toxic strains of Microcystis occurred in the western basin in 1995 and 1998, suggesting that phosphorus availability may be increasing. Various lines of evidence suggest that zebra mussel excretion of phosphorus and nitrogen has increased nutrient content of the lake, at least in the western and west central basins. Nevertheless, the highest algal concentrations occur at the mouths of the Maumee and Sandusky Rivers, around the Bass Islands, near Cleveland, and east of Long Point (frequent upwelling events) all of which provide ample nutrients. Relevance: The algae not only form the base of the pelagic foodweb, but contribute in major ways to toxin (e.g. microcystin), taste and odor (e.g., geosmin), and low oxygen (central basin) components of water quality. Trajectory: If zebra mussels are responsible for the recent cyanophyte blooms, their expansion over soft sediments suggests that Lake Erie algal blooms may continue to increase. In effect, increased internal loading of nutrients will undo progress made in limiting external loading. Future Needs: Better understanding of the role of turbulent mixing on the impact benthic zebra mussels on pelagic algae is required. We also need much more information on spatial distribution and size distribution of zebra mussels, particularly as they expand to low turbulent energy, soft substrates. Most of our data on phytoplankton distribution are from surface samples, whereas it is clear that highest concentrations may be far below the surface. Even so, remote sensing of chlorophyll distribution will enable us to better model variation in surface algal abundance under the influences of rivers, cities, and upwelling events. Seasonal variation in phosphorus, nitrogen, and silica loadings are needed desperately for modeling efforts, at a time when information is becoming increasingly scarce, particularly for the Detroit River.

Zooplankton in the Decade of Change (1988-1998).

Ora Johannsson(1) (johannssono@dfo-mpo.gc.ca), D. Culver(2), T. Johnson(3), J. Makarewicz(4), E. Mills(5), W.G. Sprules(6), and W. Taylor(7). 1. Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries & Aquatic Sciences, Canada Centre for Inland Waters, Burlington, ON; 2. Ohio State University, Columbus, OH; 3. Ontario Ministry of Natural Resources, Lake Erie Fisheries Station, Wheatley, ON; 4. SUNY Brockport Department of Biological Sciences, Brockport, N.Y.; 5. Cornell Biological Field Station, Bridgeport N.Y.; 6. Department of Zoology, Erindale College, University of Toronto, Mississauga, ON; 7. Department of Biology, University of Waterloo, Waterloo, ON.

With the invasion of Lake Erie by dreissenid mussels and Bythotrephes, a predatory cladoceran, the zooplankton community has had to adjust to reductions in food supply in some seasons and regions of the lake, to increased water clarity and increased invertebrate predation. We have observed lower levels of biomass and production and changes in vertical distribution in some regions of the lake, which might be attributed to the impact of these exotics. Observations on the stability or instability of zooplankton populations through the 1990s will be addressed to the extent that our most recent data allow and hypotheses regarding future scenarios presented.

Changes in Zoobenthos of Lake Erie: Past, Present, and Future.

T.B. Reynoldson1, R.Dermott(2) and Jan J.H. Ciborowski(3) cibor@uwindsor.ca . 1. National Water Research Institute, Environment Canada, Burlington, ON, 2. Great Lakes Lab for Fish & Aquat. Sci., Fisheries & Oceans, Canada, Burlington, ON, and 3. Dept. of Biological Sciences, University of Windsor, Windsor, ON.

No abstract available

One Fish, Two Fish, Red Fish, Blue Fish: Assessing the Lake Erie Fish Community.

Tim B. Johnson(1) tim.johnson@mnr.gov.on.ca and R.L. Knight(2). 1. Aquatic Ecosystem Science Section, Ontario Ministry of Natural Resources, Lake Erie Fisheries Station, Wheatley, ON and 2Ohio Division of Wildlife Sandusky Fisheries Research Unit, 305 East Shoreline Drive, Sandusky, OH

The fisheries resources of Lake Erie are intensively managed for sport and commercial exploitation yielding over one billion dollars annually to local economies. Through the combined effects of this exploitation, habitat alteration, and the invasion by exotic species, the fish community of Lake Erie is in a continual state of flux. Local fish communities are in turn modified by the distinct physical, chemical and trophic environment of the three lake basins, making generalizations about the fish community challenging. Lakewide harvest of all species has averaged over 21000 tonnes/year for most of the century, although species sought and characteristics of the fishery have changed through time. Percids continue to dominate the fish community, although the species complex has shifted from blue pike and sauger, to walleye and yellow perch. In recent years, benthivorous fish biomass has increased at the expense of pelagic species. A number of native species are now considered extinct (blue pike, lake herring) while others are showing signs of recovery (lake sturgeon, burbot). Invasions and introductions by non-native species have occurred for over 100 years. Some fishes are now integral parts of the food web (rainbow smelt, alewife, round gobies), while others have been controlled (sea lamprey) or declined (white perch). The Lake Erie fish community will continue to change well into the new Millennium, but the tremendous socioeconomic benefits realized in the past can continue through sound resource management.

A Modeling Perspective on the Interaction of Phosphorous Loading and Fisheries Exploitation on the Lake Erie Fish Community.

Joseph F. Koonce (jfk7@po.cwru.edu) and A.B. Locci. Department of Biology, Case Western Reserve University, Cleveland OH

After a long period of recovery, the decline of several important species during the 1990s raised concern about stability of the Lake Erie fish community. Proposed explanations for the declines included cumulative effect of reductions in phosphorus loading, effects of dreissenid mussels on pelagic productivity, and effects of predator-prey oscillations induced by the resurgence of walleye during the 1970s and 1980s. Heuristic analyses of predictions of the Lake Erie Ecological Model indicate that the instability was induced by the walleye resurgence, but also indicated that changes in lower trophic level productivity interact with fish harvest policies in complex ways. This paper reviews these heuristic analyses and compares fish community response to management policies that either integrate harvest and productivity information or base harvest decisions on historical yield patterns.

Trophic Transfer in lake Erie: A Whole Food Web Perspective.

W. Gary Sprules(1) (gsprules@cyclops.erin.utoronto.ca),O.E. Johannsson(2), E.S. Millard2, M. Munawar(2), D.S. Stewart(3), J. Tayler(4), R. Dermott(2), S.J. Whipple(1), M. Legner(1), T.J. Morris(1), D. Ghan(5), and J.M. Jech(6). 1. Department of Zoology, University of Toronto at Mississauga, Mississauga, ON; 2. Great Lakes Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, CCIW, Burlington, ON; 3. SUNY College of Environmental Sciences and Forestry, Syracuse, N.Y.; 4. Great Lakes Environmental Research Lab, NOAA, Ann Arbor, MI; 5. Department of Fisheries and Oceans, Sault Ste. Marie, ON, 6. Northeast Fisheries Science Center, Woods Hole, MA.

Recent changes in the Lake Erie ecosystem, which include reductions in smelt and yellow perch harvests, loss of deep water amphipods, reduced chlorophyll concentrations, and increased water clarity have been ascribed to reduced phosphorous loadings and the establishment of exotic species such as dreissenid mussels and Bythotrephes. We present the analysis of a trophic transfer model which quantifies patterns of energy flow through this ecosystem and can identify potential instabilities in the food web. The model comprises estimates of seasonal production and consumption of functional groups including algae, bacteria, ciliates, heterotrophic nanoflagellates, rotifers, herbivorous and predatory zooplankton as well as copepod nauplii, dreissenid adults and veligers, benthic predators and detritivores, smelt, yellow and white perch, walleye, and salmonids. A submodel is presented for each of the three Lake Erie basins. Data were collected in a series of cruises that included the whole lake as well as specific index stations. Model results, averaged over different spatial and temporal scales for the various trophic groups, reflect the average state of the food web from 1992 to 1995. Initial results indicate an enormous energy requirement by mussels that apparently cannot be met by the production of prey groups represented in the model.

Session V. Nearshore/Coastal Biotic Processes

Benthic Microbial Processes in the Coastal Region of Lake Erie: Problems and Prospects for the Foreseeable Future.

Robert T. Heath(rheath@kent.edu) and J.A. McGreevy. Department of Biological Sciences and Water Resources Research Institute Kent State University, Kent, OH

It is widely recognized that many important biogeochemical processes occurring in part or wholly in the sediments of Lake Erie coastal communities are microbially mediated. Yet the microbial taxa involved in these vital processes are largely unknown, and the factors that control their abundance and distribution are poorly identified and seldom studied. Recent advances in molecular biological techniques when applied microbial ecology now permit investigations at various levels of operational taxonomic units. Prokaryotic and eukaryotic taxa can be identified without being cultured, and various taxonomic groups can be identified in situ. Besides nutrient inputs, microbially mediated processes can be affected by interactions between sediment bacteria and bacterivorous grazers, bacterial competitors for substrate, and bacterial parasites. Our purpose here is not to provide a comprehensive review of sedimentary biogeochemical cycles but to identify new directions for benthic microbial research in the foreseeable future. Drawing on recent examples in benthic microbial ecology, we show how such studies provide novel insights in benthic processes.

Benthic Algae in Lake Erie: Past, Present and Future.

Rex L. Lowe (lowe@opie.bgsu.edu) and T.W. Stewart. Department of Biological Sciences, Bowling Green State University, Bowling Green, OH

Primary productivity of most lakes is benthic algal driven. The Great Lakes, because of their size, are an exception. Yet, benthic algae play a critical role in the littoral zone of Lake Erie and changes in littoral trophic webs have consequences for the entire lake. PreEuropean Lake Erie supported a robust and diverse benthic algal community. Cladophora, an important benthic filamentous green alga, was common but not overabundant at this time. In the late 19th and early 20th centuries changes in Lake Erie's water quality led to changes in the quantity and quality of benthic algae in the littoral zone. Increased phosphorus resulted in phytoplankton proliferations that reduced light penetration. Phosphorus loading also stimulated massive growths of Cladophora in the upper littoral zone. Much of this production was exported to deep basins where it stimulated decomposers deoxygenating the hypolimnion. As phosphorus controls were implemented in the 1970s and as zebra mussels invaded in the 1980s Lake Erie phytoplankton levels declined, light penetration increased and the benthic algal community shifted away from Cladophora blooms to a rich diverse community. Today, the benthic algal community plays an important role in littoral zone food webs and in benthic-pelagic trophic links. New exotic benthic fish are capitalizing on the benthic algal-driven food web. Predictions for a new equilibrium are difficult since anthropogenic changes in Lake Erie continue. Activities that shift the competitive advantage between phytoplankton and periphyton have profound implications for trophic pathways in Lake Erie.

Zooplankton in Canadian Coastal Marshes of Lake Erie: Association with Water Quality and Aquatic Vegetation.

Patricia Chow-Fraser (chowfras@mcmaster.ca) and V.L. Lougheed. McMaster University, Biology Department, 1280 Main St. West, Hamilton, ON

There are over 100 wetland complexes within the 2-km shoreline of Lake Erie, covering close to 27,000 ha. Forty of the Canadian complexes have been mapped and identified to specific site type; the majority of these are located in drowned river-mouths, barred estuaries, and barrier-beach lagoons. From 1995 to 1998, we visited 7 of these coastal marshes, along with one in the Detroit River, to investigate the type of zooplankton communities and their association with water quality and aquatic vegetation. Water quality in these wetlands can be ordinated along a nutrient-turbidity gradient. Marshes that are highly turbid and eutrophic, have only a few submersed aquatic plant taxa and are dominated by a fringe community of emergent and floating taxa. On the other hand, marshes that are clear and oligotrophic are associated with a higher diversity of aquatic plants that include submergent, emergent and floating taxa. According to literature on other Great Lakes coastal marshes, zooplankton communities that are associated with macrophytes differ from those associated with shallow, turbid open water that have no macrophtyes. In this paper, we investigate the appropriateness of using zooplankton as bioindicator of water-quality-plant conditions in lake-wide and long-term monitoring programs of Lake Erie marshes.

The Status of Ohio's Lake Erie Shoreline and Lacustruary Fish Communities.

Roger F. Thoma (ROGER.THOMA@EPA.STATE.OH.US) Ohio EPA, Northeast District Office, Twinsburg, OH

No abstract available

Lake Erie Amphibians and Reptiles: History, Current Status, and Future Trends.

Richard B. King(1) (rbking@niu.edu) and M.J. Oldman(2). 1. Northern Illinois University Department of Biological Sciences, DeKalb, IL and 2. Natural Heritage Information Centre (NHIC) Ontario Ministry of Natural Resources, Peterborough, ON

The amphibian and reptile fauna of Lake Erie is diverse and includes at least 56 native species (17 salamanders, 11 frogs and toads, 1 lizard, 9 turtles, 18 snakes). Two taxa are endemic to the region: the Lake Erie water snake is found only in the island region of western Lake Erie and the eastern fox snake is found only in a narrow band around parts of Lake Erie and the adjoining Great Lakes. Many amphibians and reptiles of the region have both aquatic and terrestrial phases to their life cycles and thus depend on two or more distinct habitat types. Only the mudpuppy is fully aquatic and completes its entire life cycle within Lake Erie. The distribution and abundance of virtually all Lake Erie amphibians and reptiles have declined in this century. State, provincial, or federal protection has been extended to 12 taxa found near Lake Erie and another 9 have been identified as species of special concern. Habitat loss and environmental contaminants have been major causes of these declines and will continue to impact Lake Erie amphibians and reptiles. Commercial and recreational harvest, intentional destruction, and species introductions have also contributed to declines of some species. Baseline data on distribution and abundance is needed for most species, as is data on habitat requirements and life history. Collection of such data should be combined with the establishment of an array of long-term monitoring sites where standardized census techniques can provide quantitative data on population trends on a regional basis.

Waterfowl Use of Lake Erie Wetlands.

Joel W. Ingram(1)(j_ingram@ducks.ca) and G.M. Tori(2). 1. Ducks Unlimited Canada, 566 Welham Road Barrie, ON; 2. Ducks Unlimited Inc., Ann Arbor, MI.

Great Lakes coastal wetlands and in particular Lake Erie marshes provide critical staging habitat for waterfowl. Lake Erie coastal marshes receive some of the highest spring and fall waterfowl use of all the Great Lakes wetlands. Long Point Bay in Ontario and Ohio coastal marshes are of particular importance, supporting several million waterfowl usedays each year. While fluctuations in continental waterfowl populations can strongly influence use rates of staging areas, shifts in habitat conditions and food resources can also affect waterfowl migration patterns. Current use trends of Long Point Bay and Ohio coastal marshes by certain waterfowl species cannot be explained by changes in continental population levels and it appears that local biotic processes are affecting waterfowl use rates. In particular, zebra mussel colonization appears to have resulted in increased diving duck use of Lake Erie wetlands. Scaup and bufflehead staging numbers during spring and fall migration have continued to increase despite recent declines in zebra mussel densities. Future trends and information needs will be discussed.

Changes in the Avifauna of the Western Basin of Lake Erie.

Paul Pratt (ppratt@city.windsor.on.ca) and K. Cedar. Ojibway Nature Centre. Windsor Department of Parks and Recreation, Windsor, ON.

No abstract available

Lake Erie System Model: A Fuzzy Cognitive Map to Support Development of Ecosystem Objectives.

M. Colavecchia(1), S. George(1), R. Knight(2), S. Ludsin(3), and Phil A. Ryan(4), (ryanp@gov.on.ca). 1. Environment Canada, Burlington, ON, 2. Ohio Division of Wildlife, Sandusky, OH, 3. Aquatic Ecology Lab, Ohio State University, Columbus OH, 4. Lake Erie Management Unit, Ministry of Natural Resources, Port Dover, ON.

Agencies and concerned citizens are developing ecosystem objectives for the Lake Erie Management Plan (LaMP) as directed by the GLWQA.. The level of change in the Lake Erie ecosystem precludes adoption of objectives based on return towards pristine conditions, and conflicts exist between and among stakeholder interests and agency policies. A model of ecosystem components, values, impacts and remediation measures was developed in order to explore possible system configurations. The model structure is a fuzzy cognitive map in which physical processes are typically represented as linear (phosphorus loading), while biotic responses are represented logistically as niche (Hutchinsonian-Fry) response surfaces. The model essentially provides a flexible bookkeeping function for a range of knowledge from general knowledge to peer reviewed science. All relationships are documented and can be audited. The model can be exercised by varying initial conditions and controllers, which represent human effects (e.g., land use, exploitation), in order to produce scenarios of the future. Organization of these scenarios by cluster analysis identifies potential ecosystem states. Ecosystem Objectives will be written as a characterization of a single state, selected with public consultation. This is a progress report on behalf of the EOSC sub-committees of the LaMP Workgroup and Public Forum.

Session VI. Invaders

A Century's Perspective of Changes in the Aquatic Macrophyte Flora of Western Lake Erie: What's Next?

David L. Moore (dmoore@utica.ucsu.edu). Department of Biology, Utica College of Syracuse University, Utica, N.Y.

Aquatic macrophyte communities associated with western Lake Erie were first studied systematically by Adrian J. Pieters in 1898. Since then, the marshes and associated wetlands have been impacted by both natural and anthropogenic stresses. Normal long term and short term fluctuations in precipitation in the watershed have produced periods of high and low water levels with associated impacts on the macropnyte flora. Land use has profoundly altered much of the drainage basin, shoreline and lake sediments. Throughout much of the first 75 years of this century water quality was degraded by increased sediment and nutrient loads as well as loss of macrophyte habitat. Displacement of native macrophyte flora by non-indigenous plant species has altered the macrophyte community structure. In the last 25 years, with improved sewage treatment and reduced phosphorous input, water quality has steadily improved. The introduction, spread, and mixed impacts of Dreissena polymorpha Pall. has wrought additionally profound and generally positive effects on both distribution and composition of the submersed macrophyte communities. Implementation of effective biological controls portends eventual management of Lythrum salicaria L., the principle invader of lakeassociated marshes. The submersed macrophyte communities after nearly a century of decline and simplification in structure are rebounding to the degree that in some localities they are regarded as weedy. Wetland restoration (a mixed proposition), protection, and preservation is a positive trend and continued efforts in that direction should be part of long range objectives and planning.

Lake Erie: A History of Fish Invasions and Introductions.

Edward L. Mills(1) (elm5@cornell.edu), L.D. Corkum(2), and J.H. Leach(3). 1. New York State College of Agriculture and Life Sciences, Department of Natural Resources, Cornell Biological Station, Bridgeport, NY; 2. Department of Biological Sciences, University of Windsor, Windsor, ON; 3. Ontario Ministry of Natural Resources, Lake Erie Fisheries Research Station, Wheatley, ON

No abstract available

Reassessment of Species Invasions Dogma: Lake Erie as an Example.

Hugh J. MacIsaac(1) (Hughm@uwindsor.ca), A. Ricciardi(2), and I. Grigorovich(1). 1. GLIER, University of Windsor, Windsor, ON; 2. Biology Department, University Laval, Ste-Foy, QC.

No abstract available

Session VII. Human Related Concerns

Lake Erie Angling - Past, Present, and Future.

Roger L. Knight(1) (Roger.Knight@dnr.state.oh.us), D.L. Johnson(1), and T. J. Bader(2). 1. Ohio Division of Wildlife, Sandusky Fish Research Unit, Sandusky, OH, and 2. Fairport Fish Research Unit, Fairport Harbor, OH

Angling on Lake Erie and tributaries has occurred since early human settlement. Fishing effort was minimal (by modern standards) until the mid-1900s. Key fish species included walleyes, lake sturgeon, and black bass that were seasonally available to shore-based fisheries along the coastal margin and tributaries. Boat angling increased as the region became industrialized but never attained levels evidenced in commercial fisheries. Bluepike and yellow perch were targeted species of boat anglers, particularly in the central basin. Like commercial fisheries, angling was likely reduced by the 1960s, due to population collapses of walleyes and blue-pike, and mercury contamination of fish flesh by the onset of the 1970s. Improved habitat, stemming from the Clean Water Act of 1972, coupled with newly-established interagency fisheries management for walleyes, led to unprecedented recovery of walleye stocks and an associated sport fishery. Creel assessments indicated that fishing effort on walleyes, the predominant targeted species, increased from 623,000 hours in the western and central basins during 1975 to nearly 15 million hours in 1988. Angling effort declined to about 6 million hours annually in the 1990s. A charter-boat fishery also developed, primarily in Ohio waters, and increased from about 30 licensed operators in 1975 to over 1,200 in 1990 and remained above 1,000 through the 1990s. The economic benefit of the sport fisheries in Lake Erie has been estimated at several hundred to over a billion dollars annually. Most anglers currently target walleye, yellow perch, and smallmouth bass (in order), with increased effort directed at smallmouth bass in recent years. Future levels of angling on Lake Erie will be affected by social-economic as well as biological factors.

Commercial Fishes.

Robert McGregor rob.macgregor@mnr.gov.on.ca Ontario Ministry of Natural Resources, London, ON.

No abstract Available

The Ebb and Flow of Contaminants in the Aquatic Community.

D. Michael Whittle(1) (whittlem@dfo-mpo.gc.ca), R.W. Russell, A.A. Carswell and H.A. Morrison(2). 1. DFO, Great Lakes Laboratory for Fisheries & Aquatic Sciences, Burlington, ON and 2. Aqualink, Toronto, ON

Despite Lake Erie's previous history with eutrophication problems, it has always been viewed as the cleanest of the Great Lakes with respect to toxic chemicals. In the early 1970s harvest of the fishery was curtailed because of mercury levels. Subsequent cleanup measures reduced the input of mercury. Controls on the use of DDT, PCBs and dieldrin were implemented during the same time period and resulted in declining contaminant burdens in the Lake Erie aquatic ecosystem. The invasion and proliferation of exotic species in the late 1980's changed the dynamics of contaminants in Lake Erie by altering the form and function of the food web. Previously contaminants entering from upstream sources were attached to particulars in the water column which transmitted through the system relatively quickly. The massive Dreisenna population caused a shift from a pelagic to a benthic food web. Contaminants were focused in the benthic community and retained within the system longer to increase exposure of the aquatic community. Increases in contaminant burdens were observed not only in traditional benthic feeding fish species but also in pelagic populations. Some recent compensation

has occurred but the previous rapid decline of contaminants in Lake Erie has slowed and may be further influenced by the expansion of other exotic species and perhaps the advent of climate change.

Trends in Lake Erie Colonial Waterbird Populations.

Craig E. Hebert(1) (Craig.Hebert@ec.gc.ca), D.V. Chip Weseloh(2), J. L. Shutt. 1. Canadian Wildlife Service, National Wildlife Research Centre, Hull QC and 2. CWS, Ontario Region, Downsview, ON

Populations of Lake Erie waterbirds have changed through time. Since the 1970s, the number of double-crested cormorants (Phalacrocorax auritus) breeding on the lake has increased greatly, particularly in the western basin. These birds and their offspring may pose a threat to unique island plant communities, e.g. West and East Sister Islands. Although data are limited, there is some indication that Canadian populations of herring gulls (Larus argentatus) have declined during the 1990s. Temporal changes in the herring gull diet have been detected through retrospective stable isotope analysis of archived eggs. These changes may be the result of declines in fish availability. Diet quality is an important factor regulating the success of Great Lakes herring gulls and changes in fish availability may affect colonial waterbird populations. The degree to which endocrinedisrupting contaminants may be affecting fish-eating birds is currently being assessed. Regular monitoring of colonial waterbirds will continue to provide important information regarding the dynamic Lake Erie ecosystem.

An Overview of Human Health Issues in the Great Lakes Basin.

Douglas Haines (Doug_Haines@hc-sc.gc.ca) and W.J. Bowers. Great Lakes Health Effects Program, Environmental Health Directorate, Health Canada, Ottawa, ON.

The integrity of the Great Lakes has been the subject of interest for the past 30 years with concerns about potential harmful effects of toxic chemicals on humans and wildlife. Much of the effort to understand the relationship between contaminants and health have focussed on persistent toxic substances (PTSs) like PCBs, DDT, and dioxins. Levels of DDT and other PTSs in human tissues have declined dramatically since the 1970s. However, some subpopulations (e.g., high consumers of contaminated sport fish) are at a higher risk of exposure to these substances. Health effects of concern with PTSs include cancer, reproductive, immunological and neurodevelopmental effects. Evidence from wildlife and laboratory studies, and epidemiological studies indicate that human health could be affected by PTSs. It is not clear, however, that health effects occur at current levels of exposure to these contaminants although air pollution studies have convincingly linked low levels of ozone, particulate matter and acid aerosols to increased rates of cardiorespiratory hospital admissions and mortality. Future human health issues include continued research on the effect of PTSs, especially endocrine disruptors. The health impact of air pollution will require further study and will need to be considered in policies to mitigate air pollution. The health impact of climate change will need to be assessed. These include the impacts on ambient air, drinking water and recreational water quality, the health consequences of predicted increases in extreme climatic events like severe storms and floods, and the changes in the ecological distribution of infectious parasites and other micro-organisms.

Surveillance and Monitoring in Lake Erie.

Melanie A. Neilson (Melanie.Neilson@cciw.ca), V. Richardson, D.S. Painter, and D.J. Williams. Ecosystem Health Division, Environmental Conservation Branch- Ontario Region, Environment Canada, Burlington ON

The IJC, in its 9th Biennial Report, states that "Restoration and protection of the Great Lakes basin ecosystem require strong underpinnings of essential programs - science - policy links, models and surveillance and monitoring." They have further requested that a description of programs be included as part of the Parties 1999 progress report. Based on information gathered by the Council of Great Lakes Research Managers in their 1998 inventory, and the Lake Erie LaMP Work Group inventory of activities, a summary of existing monitoring and surveillance (categorized as Loadings, Ambient and Effects Monitoring) in the Lake Erie basin will be provided.

Great Lakes Commercial Shipping: A Look Forward.

Steve Thorp (sthorp@glc.org) Great Lakes Commission, Ann Arbor, MI

In the development of the Great Lakes region, water was not just important; it was the most important factor for guiding settlement and creating a globally-significant industrial base. Nearly everything revolved around rivers, canals and the Great Lakes from exploration to trade and population settlement. It was water transportation that was the foundation of shore-based manufacturing and related activities. In many cases, the waterborne shipment option for raw material delivery and movement of finished goods was a major locational determinant. Over time with major infrastructure investment by Canada and the U.S., a highly efficient maritime system evolved that serves both domestic and overseas markets. Regional vessel and marine terminal technology led the world for many years. A maturing maritime system is facing increasing challenges ranging from maintaining adequate dredging for the long-term to responding to a dynamic world trading environment.

Indicators of Ecosystem Change - Science and Society.

Paul Bertram(1) (bertram.paul@epamail.epa.gov) and N. Stadler-Salt(2).1. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL and 2. Environment Canada - Ontario Region Office of the Regional Science Advisor, Burlington, ON.

The adequacy of a collection of indicators about Lake Erie depends on the user's perspective. Ecosystem researchers and environmental managers may require different types of data and information. Indicators selected for the State of the Lakes Ecosystem Conferences (SOLEC) are intended to assess the overall state of the Great Lakes basin ecosystem, not necessarily to answer research questions. Traditional sciences (e.g., physical, chemical, biological) are generally applied to measure ecosystem components. Human activities and decisions that affect the Great Lakes, however, are influenced by societal factors such as the economy, housing, recreation opportunities, aesthetics, etc., in addition to environmental concerns. The SOLEC indicator list contains both sciencebased and social elements. It can be sorted and rearranged to form subsets that suit individual perspectives. From the perspective of the Lake Erie basin, an assessment of the environmental compartments may be appropriate, e.g., air, water, land, biota, humans. Human-related concerns might be better represented along the lines of issues (e.g., toxics, nutrients, exotic species, habitat) or the IJC desired outcomes (e.g., fishability, drinkability, swimmability, elimination of persistent toxic substances). An information management system will be important to integrate the traditional science understanding of the Great Lakes ecosystem with the social factors that influence human activities.

Detection of Inhibition of Photosynthesis in Natural Assemblages of Lake Erie Phytoplankton by Short Exposures to Sunlight using Chlorophyll Fluorescence.

Christopher A. Marwood(1) (camarwoo@sciborg.uwaterloo.ca), R.E.H. Smith(1), M.N. Charlton(2) and B.M. Greenberg(1). 1. Department of Biology University of Waterloo, Waterloo, ON and 2. Environment Canada, National Water Research Institute, Aquatic Ecosystem Restoration Branch, Burlington, ON

The kinetics of inhibition and recovery of photosynthesis were examined in Lake Erie phytoplankton exposed to sunlight. Natural assemblages of phytoplankton from 5m depth were collected from several different sites on Lake Erie and exposed to sunlight for up to two hours. To estimate the relative effectiveness of PAR, UVA and UVB wavelengths, sunlight was filtered through plastic films with different cutoff wavelengths to create three light treatments (PAR, PAR+UVA, PAR+UVA+UVB). Following exposure to sunlight, samples of phytoplankton were either analyzed immediately or incubated in low light conditions to allow recovery. The parameters Fv/Fm, the maximum efficiency of PSII electron transport, and * F/Fm', the yield of steady-state photosynthetic electron transport, were measured rapidly from phytoplankton using pulse amplitude modulated chlorophyll fluorescence. Exposures to full sunlight resulted in almost complete inhibition of electron transport within 30min. The kinetics of inhibition and the relative contributions of PAR, UVA and UVB were quantified by fitting the observed inhibition to a model describing photoinhibition as a function of the weighted cumulative irradiance received by phytoplankton. For each of the Lake Erie stations sampled, the model predicted the observed inhibition well (R2 > 0.8). The broadband weighting coefficients estimated by the model attributed most photoinhibition to UVB in two of the three stations. UVA was also responsible for a substantial portion of the observed inhibition. PAR wavelengths inhibited electron transport less than 25% in all cases. The data were best described by a model incorporating rapid inhibition kinetics and slower recovery kinetics. Thus, UVB which accounts for only 1% of the total fluence of sunlight, accounted for most of the photodamage.

Inhibition of Photosynthesis in Natural Assemblages of Lake Erie Phytoplankton by Photoinduced Toxicity from Intact and Photomodified Polycyclic Aromatic Hydrocarbons in Sunlight.

Christopher A. Marwood(1) (camarwoo@sciborg.uwaterloo.ca), R.E.H. Smith(1), M.N. Charlton(2) and B.M. Greenberg(1). 1. Department of Biology University of Waterloo, Waterloo, ON and 2. Environment Canada, National Water Research Institute, Aquatic Ecosystem Restoration Branch, Burlington, ON

The toxicity of polycyclic aromatic hydrocarbons (PAHs) to photosynthesis in natural assemblages of Lake Erie phytoplankton was examined using chlorophyll fluorescence. Phytoplankton collected from various stations on Lake Erie were exposed in situ to three intact PAHs (anthracene, phenanthrene and fluoranthrene), and three abundant photoproducts (anthraquinone, phenathrenequinone, and 1,2-dihydroxyanthraquinone) for 30 minutes in 50% sunlight. Pulse-amplitude modulated chlorophyll fluorescence, measured from phytoplankton concentrated onto filters, was used to estimate the efficiency of photosynthetic electron transport. Both intact and photomodified PAHs diminished photosynthesis at low, environmentally relevant concentrations. Anthracene, fluoranthene and phenanthrenequinone diminished chlorophyll fluorescence in sunlight at concentrations below 300 F g/L. In addition, phenanthrenequinone also inhibited photosynthesis in phytoplankton exposed to the chemical in the dark. When transferred to low light environments for six hours, phytoplankton exposed to all PAHs except phenanthrenequinone demonstrated recovery.

Biodiversity Conservation Strategy for the Essex Region.
Dan Lebedyk (erca@wincom.net). Essex Region Conservation Authority, Essex, ON

Since the time of European settlement in the 1830s, much of the original natural resources of the Essex region have either been totally destroyed or have become extremely degraded as a direct or indirect result of clearing and drainage for timber, agriculture, and urban development. The overall loss of approximately 97% of the original wetland area and 95% of the original forest area has resulted in a highly fragmented and degraded ecosystem. The remaining small, isolated remnants of natural habitats constitute the lowest percentage of any region in all of Ontario. Environment Canada, in partnership with other government agencies, has developed "A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern" which provides a methodology to establish habitat restoration guidelines and priorities for degraded ecosystems utilizing geographical information systems (GIS) technology. The purpose of the Biodiversity Conservation Strategy is to produce a spatial database of all natural areas in the Essex region and, utilizing the Environment Canada framework, conduct an analysis of the terrestrial, wetland, and riparian habitats to identify the extent of existing natural vegetation and prioritize opportunities for habitat rehabilitation and enhancement. The objective is to increase the size, extent, and quality of key natural heritage features, natural corridors, and greenway linkages, thereby improving the ecosystem diversity and ecological functions of the Essex region. By applying the framework to the Detroit River and Wheatley Harbour Areas of Concern the Strategy will assist in addressing the delisting the impaired beneficial use - loss of fish and wildlife habitat, for these ongoing Remedial Action Plans. Current habitat conditions in all of the study areas examined to date, reveal that the remaining natural ecosystems of the Essex region are highly fragmented and degraded and hence, in need of extensive rehabilitation and restoration. Results from this report provide an overall framework to guide where habitat rehabilitation and restoration might be required before the individual sub-watershed ecosystems can be considered healthy and self-sustaining. The high priority restoration opportunity areas mapped in this report are to be used as a guide to concentrate future potential habitat restoration and enhancement works. Complete restoration of all high priority opportunity areas would lead to an "ideal" ecological condition for our remaining natural resources. It may be impractical to fulfil this optimal condition, due to the large expanse of land area, large number of private landowners involved, and lack of political will required to reach this goal. It is crucial to implement as much restoration as possible in the areas identified in this report, building upon those few remaining ecosystems remaining in the landscape. Every effort should be made to apply for funding for those landowners within the high priority areas who are willing to undertake some form of habitat restoration on their property. Only through this logical approach can we justify financial spending versus resulting ecological value.

Trace Metals in the Laurentian Great Lakes: Toxic or Tonic?
R. Michael L. McKay (rmmckay@bgnet.bgsu.edu). Department of Biological Sciences, Bowling Green State University, Bowling Green, OH

A central tenet in limnology is that phytoplankton production in lacustrine systems, including the Great Lakes, is limited primarily by availability of phosphate. Limitation by other macronutrients (N, C), let alone by trace metal micronutrients (Fe, Zn, Mn, Ni, Cu), is seldom accorded consideration. Related to the latter is a pervading attitude that most lakes are subject to a high degree of coastal and anthropogenic influence thereby ensuring a constant and plentiful supply of metals to these lakes. However, adoption of ultraclean metal sampling protocols by geochemists working on the Great Lakes has begun to clarify the status of trace metal abundance in these waters. Rather than accumulating at levels considered toxic for phytoplankton, it appears that concentrations of many trace metals are low and within the range reported for the open ocean. In this context, it is notable that low availability of trace metals, particularly Fe, is now thought to ultimately constrain oceanic phytoplankton growth and standing crop on a global scale. In this contribution, I report preliminary data obtained from surveys conducted in Lake Erie and Lake Superior during summer 1998 that addresses the Fe status of the endemic phytoplankton assemblage. Exploited in this research was a novel biochemical marker, flavodoxin, that provides an in situ assessment of phytoplankton Fe deficiency. Under conditions of Fe deficiency, the Fe-containing redox protein ferredoxin is replaced by flavodoxin as a means of reducing the cellular Fe burden. Employing an immunochemical approach for the detection of flavodoxin, results from field surveys demonstrate differential accumulation of flavodoxin over spatial and taxonomic scales in both lakes. Flavodoxin was not detected in surface water samples collected by filtration in the western basin of Lake Erie and in waters off the Keweenaw Peninsula in Lake Superior. In contrast, flavodoxin was detected in samples obtained by vertical net tow (i.e., sampling bias for large cells) both in Lake Superior and in the eastern basin of Lake Erie. The pattern of Fe deficiency that emerges from these surveys is one of a "patchy" phenomenon and one which is likely related to hydrologic and other physical parameters.

Variability in Water Quality in the Nearshore of Lake Erie Adjacent to the Mouth of the Grand River, Ontario, in 1998.

Todd Howell (howellto@ene.gov.on.ca). Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment, Toronto, ON

The Grand River is the largest tributary discharging to Lake Erie on the north shore. Hard substrate covered with dreissenid mussels, predominantly Dreissena bugensis, is abundant in the littoral zone of the lake near the river mouth. In the nearshore, high variability in water quality was anticipated, however, the range of recent conditions had not been well documented. This variability may result from loading of nutrients and particulate material from the river, water circulation along shore, and possibly the effects of dreissenid mussels on particulate levels and water clarity. In 1998, water quality surveys were conducted along approximately 15 km of shoreline adjacent to the mouth of the Grand River as part of a Lake Erie nearshore study. Extensive field measurement of chlorophyll a fluorescence, water clarity (beam attenuation), and conductivity conducted over the area augmented discrete sampling for nutrients and major ions. Results of spring, summer and fall surveys were supplemented by weekly nutrient chemistry and chlorophyll data collected at the nearby Dunnville water intake. Strong gradients in nutrient concentrations, suspended solids, chlorophyll a and conductivity associated with the plume from the Grand River were observed during spring and summer surveys. During the fall survey, high water clarity and low concentrations of chlorophyll a and particulate material were observed over much of the area. Patterns of variability in water quality will be compared with results of earlier studies in the area.

Lake Erie and the Potential Consequences of Enhanced Levels of Ultraviolet Radiation for Phytoplankton Production.

Veronique P. Hiriart(1) (vphiriar@scimail.uwaterloo.ca), R.S. Smith(1), B. Greenberg(1) and M.Charlton(2). 1. Biology Department, University of Waterloo, Waterloo, ON and 2. National Water Research Institute, Burlington, ON

Recent observations of decreasing concentrations of stratospheric ozone in the northern mid-latitudes have heightened concerns about the potential impacts of elevated ultraviolet radiation (UV-R) on temperate freshwater ecosystems. These decreases in stratospheric ozone levels coupled with the changes in water clarity Lake Erie has experienced due to nutrient loading restrictions and Dreissena sp. invasion, may reduce primary production in this large lake and have cascading effects up the food chain. In this study, the impact of UV-R on phytoplankton primary production was investigated in Lake Erie in 1997 and 1998 to explore the kinetics of photoinhibition by UV-R and assess the validity of current predictive radiation models. Carbon incorporation rates were monitored over time in lake water samples exposed to different spectral radiation treatments and biological weighting functions (BWF) were derived that quantify biological effects of UV-R as a function of wavelength. The inhibition response of photosynthesis was typically a non-linear function of weighted cumulative radiation rather than weighted instantaneous irradiance. However, in some experiments neither cumulative exposure or irradiance was very successful in describing the photoinhibitory response of the phytoplankton community. We propose here a new radiation model that incorporates both weighted UV-R dose and dose rates and allows the statistical estimation of damage and repair constants. The impacts of UV-R on Lake Erie phytoplankton communities will be estimated for a variety of UV scenarios using the predictive radiation models in conjunction with water column mixing models.

Morphological Deformities in Larval Chironomidae (Diptera) from the Western Basin of Lake Erie: An Historical Comparison.

Megan S.E. Doherty(1)(mdoherty75@hotmail.com), L.A. Hudson(1), J.J.H. Ciborowski1 and D.W. Schloesser(2). 1. Dept. of Biological Sciences & Great Lakes Inst. for Envron. Res., University of Windsor, Windsor, ON N9B 3P4, and 2. Great Lakes Science Center, US Geological Survey, Ann Arbor, MI

Chironomid larvae are an integral part of freshwater benthic communities and are often used to assess environmental quality. Contaminants can eradicate sensitive species or cause sublethal developmental or genotoxic effects. Mouthpart deformities are one indicator of sublethal effects. Historically, western Lake Erie has received contaminants and nutrients from many sources, leading to benthic community impairment. Water quality improved through the 1980's. We examined chironomid larvae collected in benthic surveys by the US EPA in 1982 and 1993 from 38 sites in Lake Erie's western basin. A total of 2,517 chironomids was individually mounted, identified, and examined for morphological deformities (extra or missing teeth in the ligula or mentum). Samples were dominated by Procladius and Coelotanypus. In 1993, both overall and site-specific generic richness were significantly greater than in 1982 (16 genera vs. 6 overall, t=3.005; p6%) compared to the baseline level of 1.55% from reference areas of Lake Erie (Gstatistic goodness of fit test = 67.20, p0.001). Larvae collected from sites extending from the mouth of the Detroit River showed the greatest incidence of deformities. Between 1982 and 1993, overall incidence of deformities decreased significantly for both Procladius and Coelotanypus. However, incidences remained elevated (3-6%) at the mouths of the Detroit and Maumee rivers. Chironomid community and deformity data appear to reflect improving water/sediment quality in western Lake Erie.

To Spawn or Not to Spawn? Growth Rate and Birth Date Comparisons in Young-of-the-Year Yellow Perch (Perca Flavescens Mitchill) Between and Inland and Small Great Lakes.

Dean G. Fitzgerald(1) ((fitzge8@uwindsor.ca), A. Dale(1), E. Kott(2), M. Thomas(3) and P.F. Sale(1). 1. University of Windsor, Department of Biological Sciences, Windsor, ON 2. Wilfrid Laurier University, Department of Biology, Waterloo, ON and 3. Michigan Department of Natural Resources, Mt. Clemens Fisheries Station, Mt. Clemens, MI

Success of temperate fish species is often predicated on synchrony of hatch and spring blooms of food resources, and maximal growth during the first year to improve sizedependent overwinter survival. During 1998, we used otolith microstructure to identify the production of two discrete cohorts of young-of-the-year (YOY) yellow perch (Perca flavescens Mitchill) in both a small inland lake (Lake Opinicon) and small Great Lake (Lake St. Clair). Lake St. Clair is subjected to large downstream flows from Lake Huron that could be the source of the second cohort of YOY fish, whereas Lake Opinicon is part of a chain of lakes that does not experience large

downstream flows. End-of-season sizes for fish that were hatched early had a mean size greater than 80 mm whereas the fish that were hatched later in the summer had a mean size less than 65 mm. The larger fish appear to have a better chance for successful overwinter survival than the smaller fish, but the relative contributions of these fish to the age-1 cohort will not be known until sampling is completed during the spring of 1999. Our results support the hypothesis that yellow perch may have the potential for more than one discrete spawning period within temperate lakes given the appropriate climatic conditions.

Burrowing Mayfly (Hexagenia) Range Expansion and Life History in Western Lake Erie.

Jan J.H. Ciborowski(1)(cibor@uwindsor.ca), L.D. Corkum(1), J. Gerlofsma1, M.E. Chase(1), A. Grgicak(1), D.W. Schloesser(2), and K.A. Krieger(3). 1. Department of Biological Sciences and Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON, 2. US Geological Survey, Great Lakes Science Center Ann Arbor, MI, and 3. Water Quality Laboratory, Heidelberg College, Tiffin, OH

Hexagenia disappeared from western Lake Erie in the 1950s. Adult Hexagenia were observed at isolated locations in 1991 following 20 years of reduced phosphorus inputs and the invasion of zebra mussels. Semi-annual benthic surveys have documented range expansion of Hexagenia larvae from west to east, and two- to four-fold annual increases in density, to >2,000 larvae/m2 at some sites in 1997. Numbers declined in many locations in 1998. Since 1994, adult Hexagenia have been observed throughout western Lake Erie but in only isolated shoreline locations in central or eastern basins. Continued absence of larvae north of Pelee Island and south of Middle and East Sister islands suggests benthic conditions may be limiting recovery in some regions. Sediment cores from areas both with and without larvae revealed presence of apparently viable eggs. Size frequency distributions of larvae in May (before emergence) of each year reflect time since site colonization. Areas apparently colonized within one year harboured almost exclusively large larvae. Sites colonized for 2 or more years exhibited distinct size bimodality or only smaller larvae. Possible explanations are 1) density-dependent effects pertain; 2) eggs may become buried to anoxic depths in sediments (arresting development) and subsequently re-exposed by either a) wave-action; or b) bioturbation activity of larger larvae. Any of these mechanisms may reduce or delay growth, and ultimately impose a two-year life cycle.

Surface Water Quality has Important Ecological Implications for Amphibian Survival.

J. D. Rouse(1), C. A. Bishop(1), and John D. Struger(2) (John.Struger@cciw.ca). 1. Canadian Wildlife Service, Burlington, ON, and Ecosystem Health Division, Environment Canada, Burlington, ON.

A number of studies from around the world including the Great Lakes basin have reported amphibian population declines. The nature, cause and extent of the decreases remain unclear. This review investigates the direct and indirect effects of agricultural chemicals on amphibian populations by a simple comparison of environmental concentrations of the chemical to known toxicological effects on amphibians and other species that play an important role in amphibian ecology. Nitrate concentrations found in agricultural watersheds of the Great Lakes region have the potential to adversely impact remaining populations of amphibians through direct lethal and development effects. Lethal and sublethal effects in amphibians are detected at 2.5 to 100 mg/L. Amphibian food sources, such as insects, and predators, such as fishes, are also affected by elevated nitrate concentrations. We found environmental concentrations of nitrate in surface waters of watersheds in the Great Lakes basin area ranging from 100mg/L. These nitrate levels fall within the range that can kill amphibian eggs and larvae. Currently no federal or provincial freshwater guidelines for the protection of aquatic life exist for nitrate. These data will also be discussed in relation to possible agricultural management strategies that might reduce nitrate concentrations in surface waters of the Great Lakes basin.