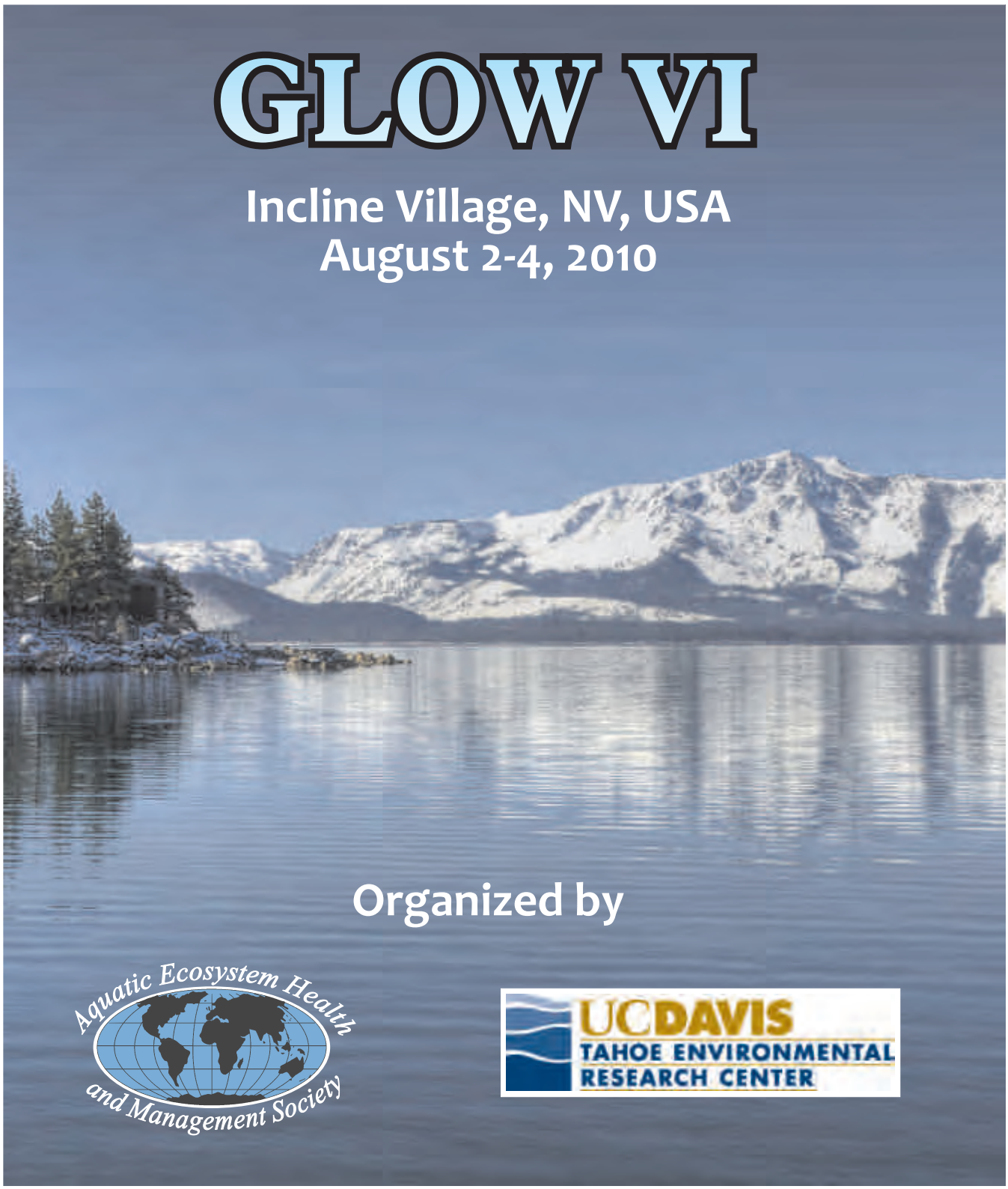
A Great Lakes of the World International Symposium

Linking Ecosystem-based Science to Management in the Great Lakes of the World

Program

GLOW VI

Incline Village, NV, USA
August 2-4, 2010



Organized by

Aquatic Ecosystem Health and Management Society

UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

An International Conference

GLOW VI

Linking Ecosystem-based Science to Management in the Great Lakes of the World

August 2nd to 4th, 2010

Lake Tahoe
Incline Village, NV

Organized by:

Aquatic Ecosystem Health and Management Society

UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER

GLOW VI

Conference Organization

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- M. Munawar (Co-chair, Canada)
- F. Roest (Netherlands)
- C. Goldman (USA)
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- L. Elder
- S. Blunt
- M. Fitzpatrick

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Welcome to GLOW VI!

The Great Lakes of the World (GLOW) Working Group was established by the Aquatic Ecosystem Health & Management Society in 1996 when the first GLOW symposium was organized at Victoria Falls, Zimbabwe. Since then the AEHMS has launched a continuing series of international symposia in order to promote interaction and communication amongst various great lakes/large lakes researchers across the world. The purpose of GLOW is to establish a global platform where ecosystem-based studies of structure, function and performance of large/great lake ecosystems is promoted, organized and synthesized. In addition, GLOW attempts to promote ecosystem, science-based management of these extensive natural resources in an integrated, multi-trophic and multi-disciplinary fashion.

A majority of the great lakes/large lakes researchers, students and managers are aware of the GLOW series of symposia as well as the resulting peer reviewed publications. These publications include special issues of the journal *AEHM* and books of the Ecovision World Monograph Series (see list of publications in tables I and II in the Introduction to AEHMS).

GLOW VI is the first meeting of GLOW to be convened in North America. It has been organized in collaboration with University of California – Davis, Tahoe Environmental Research Centre. We are pleased that the committees have developed an interesting program dealing with great/large ecosystems from the Americas, Asia, and Africa, as well as detailed and long term coverage of Lake Tahoe. The program has been categorized as described below:

1. North American Great Lakes
2. African Great Lakes
3. Asian & South American Great Lakes
4. Lake Tahoe and Crater Lake
5. Large Lake Ecosystems
6. Linking Science & Management

We greatly appreciate the assistance of Organizing, Scientific and Local Arrangements Committees towards the organization of this meeting. We sincerely thank the members of the Conference secretariat, namely Jennifer Lorimer, Lisa Elder, Susan Blunt and Mark Fitzpatrick for their hard work.

We are sure that the GLOW VI symposium in the beautiful surroundings of Lake Tahoe will be productive, interesting and generate new energy and momentum for the continued success of the AEHMS-GLOW Working Group and its symposia.

Co-chairs:

G. Schladow
Professor of Water Resources,
Environmental Engineering
Director: UC Davis Tahoe
Environmental Research Center

J. Reuter
Research Professor
Associate Director: UC Davis
Tahoe Environmental Research
Center

M. Munawar
Research Scientist:
Fisheries & Oceans Canada
President:
Aquatic Ecosystem Health
& Management Society

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An Introduction to the AEHMS

The Aquatic Ecosystem Health & Management Society (AEHMS) was established in 1989 to encourage and promote integrated, eco-systemic and holistic initiatives for the protection and conservation of aquatic resources of the world. The Society has four broad objectives centering on health, management, the convening/sponsoring of conferences/symposia, and publications via its international primary journal, monograph series and its website (www.aehms.org). The objectives of the Society are outlined below:

- Adoption and promotion of ecosystem health concept.
- Application and practice of integrated management from a multi-disciplinary, multi-trophic and sustainable perspective.
- Focusing on integrated approaches for protection, remediation, and restoration.
- Enhancing understanding of marine and freshwater aquatic ecosystems: structure, function, ecology, biodiversity, etc.
- Advocating the development of new approaches, tools, techniques and models.
- Encouraging interdisciplinary communication amongst scientists, managers, universities, governments, industry, and public sector.
- Organizing and co-sponsoring international conferences, symposia, workshops, eco-forums and working groups.
- Publication of an international primary journal, special issues and peer reviewed book series.

The Society is actively involved in primary and peer-reviewed publications. It publishes an international journal, ***Aquatic Ecosystem Health and Management (AEHM)*** on a quarterly basis (in collaboration with the publisher Taylor and Francis, Philadelphia). From 2007 onwards the AEHM was selected by Thomson Scientific for coverage in the Science Citation Index Expanded (SciSearch®); Journal Citation Reports; Current Contents®/Agriculture, Biology, and Environmental Sciences; Zoological Record; Biological Abstracts; and BIOSIS Previews. It has published over **30** special issues on diverse topics from across the world. Currently, plans are under way for publication on: the ecosystem health and recovery of Bay of Quinte, Lake Ontario; ecology of Lake Superior; and, Vallentyne & Vollenweider memorial special issues. Table 1 provides a general picture (also see www.aehms.org).

Table 1. Special issues of the Aquatic Ecosystem Health and Management Journal 2000-2009.

Special issues	Volume	Year
Large Lakes of the World: Comparative Ecology	Vol 3 (1)	2000
Ecosystem Health of Lake Baikal, Russia	Vol 3 (2)	2000
Great Lakes of the World: Food Web, Fisheries, and Management	Vol 5 (3)	2002
Comparing Great Lakes of the World	Vol 6(3)	2003
Coastal Wetlands of the Laurentian Great Lakes: Health, Integrity and Management	Vol 7(2)	2004
Emerging Issues in Lake Superior Research	Vol 7(4)	2004
Great Lake Victoria Fisheries: Changes, Sustainability, and Building Blocks for Management	Vol 10(4)	2007
Changing Great Lakes of the World (GLOW IV)	Vol 11(1)	2008
State of Lake Huron: Ecosystem Change, Habitat, and Management, Part I	Vol 11(2)	2008
Checking the Pulse of Lake Ontario	Vol 11(4)	2008
The State of Lake Huron: Ecosystem Change, Habitat and Management, Part II	Vol 12(1)	2009

In addition, the AEHMS also produces a peer reviewed book series under the banner of the ***Ecovison World Monograph Series***. It has already published over 20 peer reviewed books on a variety of subjects and aquatic environments (see table 2).

Table 2. Books published under Ecovision World Monograph Series from 1995-2009.

Books	**Year**
The Lake Huron Ecosystem: Ecology, Fisheries and the Management	1995
Phytoplankton Dynamics in the North American Great Lakes, Vol. 1: Lakes Ontario, Erie and St. Clair	1996
The State of Lake Erie Ecosystem (SOLE): Past Present and Future	1999
Phytoplankton Dynamics in the North American Great Lakes, Vol. 2.: Lakes Superior, Michigan, North Channel, Georgian Bay and Lake Huron	2000
The Great Lakes of the World (GLOW): Food-web, Health & Integrity	2001
Ecology, culture and conservation of a protected area: Fathom Five National Marine Park, Canada	2001
State of Lake Ontario(SOLO): Past, Present and Future	2003
State of Lake Michigan (SOLM): Ecology, Health and Management	2005
Checking the Pulse of Lake Erie (CPOLE)	2008
State of Lake Superior (SOLS)	2009

The Society welcomes individuals for membership belonging to a wide range of disciplines. AEHMS cordially invites to join the Society to support global conservation and education. Membership includes 4 quarterly issues of the journal with on-line access as well as discounts on conference registration fees, purchases of Ecovision books and back issues of our journal. A discounted membership is available for the participants of this conference, students and retired colleagues.

M. Munawar
President:
Aquatic Ecosystem Health & Management Society

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General Information & Publication Plans

Badges
You should consider your personal name badge as a valuable entry ticket. Please wear your badge at all times during the conference.

Coffee and tea breaks
Coffee/tea breaks are included with registration. The locations will be announced at the time of the conference.

Registration Desk
The registration desk will be available at 8:30 am on Monday before the conference and throughout the conference at the venue.

Scenic Tour
An optional 3-4 hour bus tour around the 120 km perimeter of Lake Tahoe will also be available Wednesday afternoon, following the conference closing remarks. Additional spots may be available for booking during the conference at the registration desk.

Participants will be able to visit the lake at special designated points of interest, drive through the natural forested landscape, stop at scenic Emerald Bay, tour stream sampling locations in the watershed, observe erosion control projects and tour facilities designed to treat urban runoff. The tour will start and stop at the TCES facility in Incline Village and lunch will be provided en route. Scientists working at Lake Tahoe will be accompanying the tour.

Publication Plans
Aquatic Ecosystem Health and Management is an ISI rated international primary journal published by Taylor & Francis, Philadelphia. Presenters are encouraged to submit manuscripts to the *AEHM* for consideration for publication subject to the AEHMS instructions to authors, guidelines and page charges (www.aehms.org). Due to limited space, AEHMS has set page limit guidelines as follows: Keynote: 10; Oral & Poster: 6 printed pages including tables and figures (Text: Times New Roman 11 pt, Margins: 2.7 cm (1”), Paper: letter size 21.6x28 cm (8.5x11”)). For more information please contact Dr. M. Munawar, Chief Editor (mohi.munawar@dfo-mpo.gc.ca).

Presenters who are planning to publish in the special issues are requested to complete the publication questionnaire and return it the Registration Desk or by email to jennifer.lorimer@dfo-mpo.gc.ca before the end of the conference.

Liability
Neither the conference organization, the UC Davis Tahoe Environmental Research Center, nor the AEHMS can be held responsible for damage, loss or theft during the conference.

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Program-at-a-Glance

Monday, May 3		Tuesday, May 4		Wednesday, May 5	
8:30-9:00	Registration	*8:30-9:50*	Session 3	*8:30-9:50*	Session 5
9:00-9:20	Opening remarks				
9:20-10:00	Plenary by C.K. Minns				
10:00-10:20	Break	*9:50-10:10*	Break	*9:50-10:30*	Break
10:20-11:00	Plenary by J. Kelly	*10:10-10:50*	Plenary by C.R. Goldman	*10:30-12:00*	Session 6
11:00-12:20	Session 1	*10:50-12:10*	Session 4	*12:00*	Adjournment
12:20-1:20	Lunch	*12:10-1:10*	Lunch		
1:20-2:00	Plenary by T.F. Nalepa	*1:10-3:20*	Session 4		
2:00-3:00	Session 1				
3:00-3:20	Break	*3:20-3:40*	Break		
3:20-5:20	Session 2	*3:40-5:40*	Session 4		
		6:00	BBQ Dinner		

Sessions

1 North American Great Lakes
2 African Great Lakes
3 Asian & South American Great Lakes
4 Lake Tahoe & Crater Lake
5 Large Lake Ecosystems
6 Linking Science & Management

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Detailed Scientific Program

Monday, Aug 2nd			
8:30	9:00	Registration	
9:00	9:10	*Welcome*	
9:10	9:20	*Opening Remarks*	
9:20	10:00	*Plenary by C.K. Minns*	*The Science Of Ecosystem-Based Management In The Great Lakes: Status, Progress & Emerging Issues*
10:00	10:20	Break	
		Session 1. North American Great Lakes	
10:20	11:00	*Plenary by J.R. Kelly & P.M. Yurista*	*Approaches to integrated assessment of large lakes involving new survey designs and synoptic,* in situ *technologies*
11:00	11:20	M. Munawar, I.F. Munawar, M. Fitzpatrick, H. Niblock &, J. Lorimer	Comparing the microbial - planktonic food webs of the Laurentian Great Lakes
11:20	11:40	R.T. Heath	Significance of N and P Co-Limitation of Phytoplankton Growth in Lake Erie
11:40	12:00	M. Munawar & M. Fitzpatrick	Deteriorating health of the coastal regions of the Great Lakes: searching for ecosystem based management strategies
12:00	12:20	D.D. Kane, D.A. Culver & M. Munawar,	The Planktonic Index of Biotic Integrity (P-IBI): A Technique for Linking Ecosystem-based Science to Management in the Great Lakes of the World
12:20	1:20	Lunch	
1:20	2:00	*Plenary by T.F. Nalepa*	*The Global Threat of Invasive Species to Large, Freshwater Lakes: the Laurentian Great Lakes as an Example*
2:00	2:20	R.W. Flint	Lake Ontario Strategies in Conflict: Nutrient Control and Fish Stocking
2:20	2:40	J.F. Atkinson, S. Brown, & Y. Feng,	Web-based decision-support modeling in the Great Lakes
2:40	3:00	W.G. Booty, L.F. Leon, I. Wong, C. Mccrimmon, G. Benoy & J. Vanrobaeys	Integration of Watershed and Lake Modeling in the Lake Winnipeg Basin
3:00	3:20	Break	
		Session 2. African Great Lakes	
3:20	3:40	M. Van Der Knaap	Status of fisheries management on Lake Tanganyika
3:40	4:00	S.A.E. Marijnissen, P.-D. Plisnier, L. Ntahuga, H. Mwima & A. Yamamoto	Environmental Management in the Lake Tanganyika Basin: Uniting Science, Politics, and Pragmatism in a Transboundary Monitoring Framework
4:00	4:20	M.I. Mccarthy & K.L. Smith	Cascading Impacts of Global Warming on Lake Victoria
4:20	4:40	P.A. Fuerst, L. Kaufman & W.W. Mwanja	Genetic Biodiversity and Management of Inland Fisheries: Options for Management of the Cichlid Fauna of the Lake Victoria Region
4:40	5:00	M. Njiru & M. Van Der Knaap	Is the ecosystem approach the way forward for Lake Victoria's fisheries?
5:00	5:20	W.W. Mwanja & J. Balirwa	Trends in key fisheries on major lakes in Uganda: management options for sustainable production

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Tuesday, August 3rd			
		Session 3. Asian & South American Great Lakes	
8:30	8:50	N.M. Pronin, B.B. Bazarova, D.V. Matafonov & A.S. Kolosovich	The invasive macrophyte *Elodea canadensis* in Lake Baikal and the watersheds of the Arctic and Pacific Oceans
8:50	9:10	P.J.W. Roberts, B. Villegas & M. Libhaber	Modeling urbanization effects on Lake Titicaca
9:10	9:30	J.L. Blanco, S. Rosales, Hae-C. Kim & S. Son	Modeling Ecosystem Carrying Capacity on Lake Titicaca
9:30	9:50	D. Kalen Su & J. Vera	Contributions towards an ecosystem based management of Lake Titicaca basin
9:50	10:10	Break	
		Session 4. Lake Tahoe and Crater Lake	
10:10	10:50	*Plenary by C.R. Goldman*	*Management-driven Limnological Research at Lake Tahoe, USA*
10:50	11:10	J.E. Reuter, S.H. Hackley, T.A. Cahill & A. Gertler	Atmospheric Deposition of Nitrogen and Phosphorus to Lake Tahoe, CA-NV, USA
11:10	11:30	J.M. Thomas, A.C. Heyvaert, T. Mihevc, C.E. Thodal, K.K. Allander, T.G. Rowe & J.E. Reuter	Groundwater is an Important Source of Nutrient Loading to Lake Tahoe, CA-NV, USA
11:30	11:50	A.C. Heyvaert, J.M. Thomas, J.E. Reuter & S.G. Schladow	Characteristics and patterns of urban stormwater runoff into Lake Tahoe
11:50	12:10	D.A. Hunter, M. Winder & C.R. Goldman	Phytoplankton Assemblage Characteristics for Lake Tahoe, CA-NV, USA
12:10	1:10	Lunch	
1:10	1:30	R. Coats, J. Riverson, B. Wolfe & M. Costa-Cabral	Climate change impacts in the Tahoe Region: past and projected future trends
1:30	1:50	G.B. Sahoo, S.G. Schladow, J.E. Reuter & R. Coats	Water Quality of Deep Lakes in Response to Climate Change
1:50	2:10	J.E. Reuter, G.B. Sahoo, S.G. Schladow, J. Riverson, J. Sokulsky, D. Roberts & A.C. Heyvaert	Development of Numeric Load Reduction Targets for Lake Tahoe, CA-NV, USA
2:10	2:30	A. Caires, S. Chandra, M. Wittmann & G. Schladow	Long-term change in benthic invertebrate assemblages in Lake Tahoe, California/Nevada
2:30	2:50	M.E. Wittmann, J.E. Reuter, S. Chandra, S. G. Schladow & B.C. Allen	Asian clam (*Corbicula fluminea*) invasion in Lake Tahoe: The ecology and management of an invasive bivalve in an oligotrophic lake
2:50	3:20	K.L. Ngai, S. Chandra, M. Kamerath, T. Steissberg & B.C. Allen	Nonnative largemouth bass (*Micropterus salmoides*) in Lake Tahoe: movement, potential for establishment, and predation impact
3:20	3:40	Break	
3:40	4:00	S.G. Schladow, M. Wittmann, A. Forrest, F.J. Rueda, J.E. Reuter, S. Chandra, T.E. Steissberg, V. Schmidt, N. Raineault, B. Laval & A.C. Trembanis	Physical Limnology's Role in the Distribution and Spread of Invasive Species in Lake Tahoe
4:00	4:20	D.M. Nover, S. Andrews, T. Schuler, J.E. Reuter, M. Kumagai, S. Girdner & S.G. Schladow	Particle size distribution in lakes of varying geology, watershed size, and urban development: Fine particle sources and implications for management

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Tuesday, August 3rd			
4:20	4:40	S.W. Andrews, D.M. Nover, S.G. Schladow, D.A. Hunter, M. Winder, J. Reuter, S. Girdner & B.R. Hargreaves	Suspended particle identification in two deep oligotrophic lakes: linking optical measurements to microscope samples at Crater Lake and Lake Tahoe
4:40	5:00	B.R. Hargreaves, A. Vaidya & S.F. Girdner	An initial bio-optical comparison of deep ultra-oligotrophic lakes with differing human impact: Lake Tahoe and Crater Lake
5:00	5:20	S.F. Girdner & M. Buktenica	Twenty-five years of monitoring Crater Lake: an ultra-oligotrophic lake
5:20	5:40	T.G. Rowe & N.L. Alvarez	Lake Tahoe Interagency Monitoring Program – An Integral Part of Science in the Lake Tahoe Basin
6:00		Barbeque Dinner	

Wednesday, August 4th			
		Session 4. Large lake ecosystems	
8:30	8:50	J.R. Corman, S. Chandra, C. Davis, M. Dix, N. Girón, E. Rejmánková, A. Roegner, J. Veselam & J.J. Elser	Phytoplankton nutrient and light limitation in Lake Atitlán, Guatemala
8:50	9:10	N. Giron, E. Rejmánková, J. Komárek, J. Komárková & M. Dix	Cyanobacterial Blooms in Lake Atitlan, Guatemala
9:10	9:30	M.J. Maarse, V. Harezlak & M. Haasnoot	Exploring the effects of climate change and spatial planning on habitats in Lake IJsselmeer, the Netherlands
9:30	9:50	C. Levitan, C. Hall, B. Ellis, J. Stanford & B. Nass	Dynamic simulation of basic physical, chemical, and biological processes of a large oligotrophic lake in Montana
9:50	10:30	Break	
		Session 5. Linking Science & Management	
10:30	11:30	Panel Discussion & Synthesis	
11:30	11:40	Publication plans	
11:40	12:00	Conclusions & Overview	
	12:00	Adjournment	

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Abstracts

Alphabetical order by presenting author

<u>ANDREWS, S.W.</u>, NOVER, D.M., SCHLADOW, S.G., HUNTER, D.A., WINDER, M., REUTER, J., GIRDNER, S., HARGREAVES, B.R.

Tahoe Environmental Research Center, University of California, Davis, CA 95616 USA or Department of Civil and Environmental Engineering, University of California, Davis, CA 95616 USA
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Suspended particle identification in two deep oligotrophic lakes: linking optical measurements to microscope samples at Crater Lake and Lake Tahoe

Suspended particles in oligotrophic mountain lakes vary greatly in size and composition: from small bacteria and inorganic mineral grains to midsize diatoms to large, heterogeneous flocs. Accurate determination of the size distribution and bulk particle composition, which is known to shift seasonally between dominantly inorganic particles during spring snowmelt, to organic particles during autumn and winter, is essential for understanding ecosystem function and organizing monitoring and management programs for lake clarity. In this study, we use three in-situ optical instruments: a LISST-100X particle size analyzer, a HydroScat backscatter sensor, and a Turner C6 multichannel fluorometer, along with a Seabird CTD profiler to measure the optical and physiochemical properties of Lake Tahoe, CA-NV and Crater Lake, OR during the summer of 2009. Microscope analysis of the particle size distribution and classification of the phytoplankton community were performed at both sites on two sampling dates. Results indicate a general dominance of organic particles at Lake Tahoe, with the diatom genus *Cyclotella* representing most of the particles; while Crater Lake had a more mixed ensemble of organic and inorganic particles. Both lakes showed evidence of photo-acclimation, with maximums of particulate organic matter located 10-30 meters above chlorophyll fluorescence maximums. Microscope analysis indicated that the optical instruments were correctly able to categorize the phytoplankton community and the total numbers of particles in suspension.

ATKINSON, J.F., BROWN, S., AND FENG, Y.

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Web-based decision-support modelling in the Great Lakes

While significant gains have been made in developing simulation models for large lake systems, including hydrodynamics (circulation), biological, and chemical fate and transport, there is still a long process to transfer model results and capabilities to resource managers and the public at large. Notable exceptions exist, such as the Great Lakes Coastal Forecasting System (GLCFS) maintained through the Great Lakes Environmental Research Laboratory (GLERL) for the Laurentian Great Lakes of North America, or the system of models used in the Chesapeake Bay Program. Those models provide certain information such as general current speed, sediment loadings, wave height, etc., and can be used for longer-term simulations or even for some forecasting purposes (in the case of the GLCFS, at least), but are not interactive. In this project we develop a particle tracking application linked with a hydrodynamic model that can be run as a web application, based either on current, historical, or forecast meteorological conditions. Particle tracking provides a simple interpolation of the hydrodynamic calculations that can be easily visualized, providing simple graphical representations of flow conditions. Example applications are discussed for algal blooms and chemical spills, where a water intake or beach manager can determine the projected trajectory of the bloom or spill over several days and decide whether a management response is needed to protect a given facility. This type of modelling capability provides a new component for very short-term management decision making needs in a large lake.

BLANCO, J.L., ROSALES, S., KIM, H.-C., AND SON, S.

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Modeling Ecosystem Carrying Capacity on Lake Titicaca

Lake Titicaca has great cultural and social importance for the developing countries that surround it. Considering the fragility of the ecosystem, many of the productive activities related to the lake, such as fish farming, can cause irreversibly damage. Through an agreement between the Old Dominion University (USA) and the Hispanic Peruvian Cooperation Fund (FONCHIP, Peru), we are conducting a project to model the carrying capacity of Lake Titicaca. This includes the implementation of an ecosystem model coupled with a hydrodynamic numerical model. The project has just begun, along with the installation of four digital weather stations, four sensors to measure the lake level, and one acoustics current meter. Also being considered is the setup of several weekly water-quality monitoring stations and seasonal limnological cruises. This information will define the dynamics and main forces of the lake, and validate the model results. Additionally, color images (chlorophyll) from satellite MODIS for the period 2002 to 2009, were processed and monthly climatology was assessed. This climatology showed a higher relative productivity in fall and winter, contrary to what occurs in most ecosystems. We hypothesized that the increased production in fall-winter (dry season) was due to an increase in the net solar radiation (no clouds), and wind behavior increased mixing or produced upwelling of higher nutrient water.

BOOTY, W.G., LEON, L.F., WONG, I., MCCRIMMON, C., BENOY, G., AND VANROBAEYS, J.

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Integration of Watershed and Lake Modeling in the Lake Winnipeg Basin

Estimating non-point source pollution from watersheds and the effects of mitigation measures (e.g. beneficial management practices or BMPs) is an important step in managing and protecting water quality, not only at the basin level where it originates, but also at the receiving waters such as reservoirs, lakes or oceans. Lake Winnipeg is a prime example of such land-lake interactions, where eutrophication and increased algal blooms in the lake are fueled, as evidence suggests, from agricultural sources of nutrients in the region. Simulation models at the watershed level have been applied to aid in the understanding and management of surface runoff, nutrients and sediment transport processes. Similarly, models with different degrees of complexity are used to simulate the aquatic ecology and water quality in lakes. The Soil and Water Assessment Tool (SWAT) is a widely known watershed model, which provides estimations of runoff, sediment yield, and nutrient loads at a sub-basin level. SWAT has been applied to three pilot watersheds on the Lake Winnipeg basin in order to investigate the impacts and uncertainties of different BMPs on nutrient loading in the targeted catchment areas. OpenMI and OpenMP have been used to link the SWAT model with in-lake models, which allows for integrated calibration/validation and propagation of uncertainties. We also explore the use of multi-objective optimization modelling to determine the best solutions to achieve water quality objectives.

CAIRES, A., CHANDRA, S., WITTMANN, M., AND SCHLADOW, G.

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Long-term change in benthic invertebrate assemblages in Lake Tahoe, California/Nevada

Benthic invertebrates in deepwater lakes are useful biological indicators because of their sensitivity to changes in biological and physical characteristics of lakes. Both the biological and physical characteristics of Lake Tahoe have changed substantially since the 1960s, when the last comprehensive benthic invertebrate survey was conducted. To document differences in the benthic invertebrate community in Lake Tahoe since the 1960s, we collected samples along 4 transects (Crystal Bay, McKinney Bay, Stateline, and Camp Richardson) from June-August 2008 and May-September 2009. Samples were collected at similar depth intervals for each transect from 0-500 meters. We compared our collections to those of the 1960s. Lakewide-weighted total benthic invertebrate density has declined 87% since then. Oligochaeta was the most common taxon observed in our samples. Lakewide-weighted oligochaete density has declined 79% since the 1960s. Chironomidae was the second most abundant taxon collected and its density has declined 65% since the 1960s. Two unique endemic taxa, the stonefly *Capnia lacustra* and blind amphipod *Stygobromus* spp., are still present in the lake, but their densities have declined dramatically (98%, and 99%, respectively). Macrophyte occurrence in benthic samples today is also much less frequent. We discuss whether a reduction in deepwater plant abundance, coupled with increasing numbers of introduced aquatic species (e.g. crayfish and mysid shrimp) can provide explanations for the observed decline in aquatic invertebrate densities in Lake Tahoe.

CORMAN, J.R., CHANDRA, S., DAVIS, C., DIX, M., GIRÓN, N., REJMÁNKOVÁ, E., ROEGNER, A., VESELAM, J., AND ELSER, J.J.

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Phytoplankton nutrient and light limitation in Lake Atitlán, Guatemala

Lake eutrophication can lead to substantial changes in ecosystem function and services. Phosphorus concentrations in Lake Atitlán, a deep (max depth = 340 m), tropical lake in the Guatemalan highlands, have increased during the last 30 – 40 years, shifting the lake away from an oligotrophic state. In late 2008 and 2009, there were major cyanobacterial blooms in the lake. Lake sestonic carbon to nitrogen to phosphorus (C:N:P) ratios from these time periods suggest phytoplankton nutrient limitation may shift between either nitrogen or phosphorus. In April 2010, we performed a short-term pelagic nutrient and light limitation bioassay in Lake Atitlán. Water samples were collected to represent the epilimnetic, metalimnetic, and hypolimnetic phytoplankton communities. Bottles were incubated in situ and amended with N, P, N and P, or trace elements, or were not amended. Epilimnetic treatments were incubated at three different depths to vary light availability. Changes to chlorophyll *a* concentrations indicated a shift in phytoplankton growth limitation from nitrogen and phosphorus co-limitation in the epilimnion, with light increasing this response positively, to only nitrogen limitation in the metalimnion. A chlorophyll *a* response was not detected in the hypolimnion; trace elements were not found to be limiting at any depth. This experiment represents the first bioassay in Lake Atitlán and a platform for continued limnological surveys. These results highlight the need to consider factors that impact both nitrogen and phosphorus dynamics to alleviate eutrophication in this tropical lake.

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Climate change impacts in the Tahoe Region: past and projected future trends

Analysis of 20th century air temperature, snowfall, stream discharge and lake temperature records in the Tahoe Basin indicated strong upward trends in air temperature, a shift from snow to rain, a shift in snowmelt timing to earlier dates, increased rainfall intensity, and increased interannual variability of precipitation. With down-scaled and bias-corrected output from two General Circulation Models (the Geophysical Fluid Dynamics Laboratory, or GFDL, and the Parallel Climate Model, or PCM) and two emissions scenarios (A2 and B1), together with a distributed hydrologic model, we can now project future trends in temperature, precipitation, drought conditions and flood frequency for the Basin. The steepest trend (GFDL with A2) indicated about 5 ^{o}C warming by the end of the 21st century. Precipitation trends are more modest with a slight dip in the latter half of the 21st century indicated by the GFDL/A2 case, but not the others. Comparisons with the Palmer Drought Severity Index show that drought will increase (especially on the drier east side of the basin) in spite of the lack of strong trends in precipitation. The magnitude of the expected 100-yr flood may increase up to 3-fold by mid to late century, but decline thereafter. Continued warming in the Tahoe basin is likely to result in 1) increased tree mortality, and increased fuel loads; 2) increased wildfire frequency and intensity; 3) continued shift from snow to rain; 4) increased intensity of rainfall, with concomitant increases in surface soil erosion and channel erosion; 5) changes in the theoretical climax vegetation. The management response to these climate change impacts may include aggressive fuel load reduction, establishment of plant communities and species adapted to lower elevations, more erosion control projects, modified bridge design, and redoubled efforts to control nutrient and fine sediment flux to the lake.

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Deteriorating health of the coastal regions of the Great Lakes: searching for ecosystem based management strategies

Coastal or nearshore regions of the North American Great Lakes are unique and dynamic ecosystems due to physical, chemical and biological processes, as well as human activities. These coastal systems are impacted by continued eutrophication, invasive species and global warming. Coastal ecosystems are also recipients of excessive nutrients, contaminants and other organic material from rivers and tributaries. Other natural phenomenon, such as the formation of a thermal bar in some of lakes, also results in the segregation of coastal and offshore waters. In recent times, emerging stressors including the advent and expansion of exotic species (e.g. dreissenid mussels, Cercopagus, Hemimysis) as well as global warming, seem to have adversely affected the health and integrity of most of the coastal regions. This paper attempts to assess and compare the microbial and planktonic food web characteristics of coastal vs. mid lake regions. Such comparisons are critical to draw the attention of researchers and managers to the rapidly deteriorating health of the coastal regions of the Great Lakes and the urgent need for new management strategies.

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Lake Ontario Strategies in Conflict: Nutrient Control and Fish Stocking

Productivity and health of the Laurentian Great Lakes are maintained by synergistic actions of many factors, none of which act independently with similar results. For decades, questions have been raised regarding conflicts in resource management strategies of these lakes that simultaneously target nutrient control limiting productivity and emphasize salmonid fish stocking enhancing lake productivity. Further uncertainty arises from inadequate knowledge of feedback processes between food web manipulations and effects on nutrient cycling. For example, water quality changes have occurred in Lake Ontario at rates and in ways that are different from what would be expected. Phosphorus loading has decreased since the early 1970s, while inorganic nitrogen has increased. It is widely believed that reversals in eutrophication have been largely the result of intensive nutrient abatement programs that have decreased system productivity. Likewise, phytoplankton biomass has exhibited a decline over the early 1970s and chlorophyll *a* measures, although more variable, have also demonstrated a decline. Top predator biomass, on the other hand, has shown a major increase, supported in part by stocking programs which have resulted in increased system productivity. Whereas changes in external nutrient loadings for Lake Ontario may affect structure and productivity of phytoplankton communities, it is believed from many "top-down" studies that composition of higher trophic levels in the lake can also potentially exert influences over the structure and productivity of phytoplankton. Therefore, it is important that we take a holistic, ecosystem approach so that all factors influencing biological productivity are integrated into a picture of comprehensive system function. It will then be possible to identify factors contributing to control of system dynamics and to gain a perspective on the predominant influences on functioning. Here the merit of issues regarding the balance between nutrients and the lake ecosystem's food web are explored. Empirical models from other lake systems on phytoplankton production and fish productivity illustrate that similar data from Lake Ontario fall outside predicted patterns. These trends suggest we seek better understanding for the two primary ends of the spectrum that potentially will mean the difference between a healthy ecosystem, in contrast to one that is stressed from continual reliance on management strategies in conflict.

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Twenty-five years of monitoring Crater Lake: an ultra-oligotrophic lake

Crater Lake, Oregon, is an ultra-oligotrophic, deep lake that symbolizes one end of the productivity spectrum. This talk will explore physical, chemical, and biological characteristics documented by a twenty-five year monitoring and research program. Crater Lake is one of the clearest large lakes in the world, characterized by extremely low nutrients, a diverse phytoplankton community, a deep primary productivity maximum, an even deeper chlorophyll maximum, high dissolved oxygen concentrations, a deepwater nutrient pool, an extreme clarity to ultra-violet light, and a remarkable deepwater moss community. The setting of Crater Lake within a National Park at the crest of the Cascade Mountains isolates this lake from most anthropogenic influences, making it a unique setting in which to assess the impact of regional and global climate change on high elevation oligotrophic lake systems.

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Cyanobacterial blooms in Lake Atitlan, Guatemala

Uncontrolled nutrient input into Lake Atitlan over the last few decades has lead to water pollution and recent cyanobacterial blooms. The first bloom occurred in December of 2008, followed by a more extensive bloom in October 2009. Although several studies have been conducted at the lake, there are few recent baseline data to help understand the interaction between the blooms, the lake and its watershed.

Water samples for nutrient and chlorophyll analyses were collected from surface water from replicated locations. The acetylene reduction technique was employed to estimate cyanobacterial nitrogen fixation by the reduction of acetylene to ethylene by nitrogenase.

The cyanobacteria blooms were identified as planktonic *Lyngbya hieronymusii/birgei/robusta* complex. Remote sensing images documented that at the maximum bloom development, 40% of the 137 km^2 of the lake area were covered by dense patches of *Lyngbya*, with the chlorophyll *a* concentration reaching over 100 µg L^{-1}. The nitrogen fixation followed a pattern expected in non-hetercystous cyanobacteria, i.e., the nitrogenase activity was minimal during the day, while during the night the activity reached 2.2 nmol C_2H_4 µg Ch a^{-1} h^{-1}. The cell C, N and P content was 36.7%, 5.9% and 0.9%, respectively, resulting in the molar ratio of 105:14.4:1.

A well designed and executed lake monitoring program, strict control of nutrient input into the lake, and public education are extremely necessary. Without remediation, this may present a threat to local communities, who depend on the lake for their livelihood, as well as lead to the loss of Atitlan's unique aesthetic status.

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Management-driven limnological research at Lake Tahoe, USA

The growing number of environmental stresses on aquatic ecosystems worldwide has lead to a more rapid conversion of basic limnological studies into sound management practices. Nowhere has this been more clearly demonstrated than in the development of hydroelectric reservoirs, the protection of drinking water sources, and the conservation of recreational lakes. Lake Tahoe lies in the Sierra Nevada Mountains between the border of California and Nevada, and is internationally renowned for its remarkable transparency, cobalt blue waters, and magnificent sub-alpine setting. A half century of monitoring shows that Secchi depth has declined by 10 m since 1968 and that the rate of ^{14}C primary productivity continues to increase at about 5% per year. Thick growths of attached algae have covered portions of the once-pristine shoreline and like many of the world's lakes, Tahoe has been affected by non-native species that were either intentionally introduced or are part of regional invasions. Since the early 1960s when basic limnological experiments were used to stop sewage effluent from being disposed directly to the bottom of the lake, research and monitoring has been central to the management of aquatic resources in the Lake Tahoe Basin. Other examples of controversy-driven studies at Lake Tahoe include, but are not limited to climate change, gasoline and MTBA pollution from watercraft and localized groundwater contamination, establishing numeric targets for nutrient and sediment reduction, wildfires and water quality, atmospheric deposition, design of landscape restoration and best management practices to repair the impacts of urbanization and land disturbance, and protection of wetlands and riparian habitat. A visit by the US President and Vice President together with programs of active engagement with the public, resource managers and decision-makers, as well as routine outreach to children, requires time and effort but eventually fosters a much more informed public. The simple message of "Keep Tahoe Blue" adopted by the League to Save Lake Tahoe has great appeal and has been extremely successful over the years.

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An initial bio-optical comparison of deep ultra-oligotrophic lakes with differing human impact: Lake Tahoe and Crater Lake

Bio-optical measurements during July 2009 in Lake Tahoe (California-Nevada,USA) and August 2009 in Crater Lake (Oregon USA) for the first time allow direct comparison of these two lakes with a suite of bio-optical measurements. At the index site off Ward Creek in Lake Tahoe the upper mixed layer was more turbid and had higher CDOM fluorescence than the center station of Crater Lake. The chlorophyll-*a* concentration was similar when integrated per unit surface area but the deep chlorophyll maximum was at 60m for Lake Tahoe compared to 120m for Crater Lake. In both lakes the phytoplankton relative absorbance of UV-B solar radiation (likely via MAA pigments) varied inversely with depth. Future sampling at other stations and dates in both lakes with the same instruments will be needed to determine if these differences are typical.

These lakes have been suggested to be optically similar; both are extremely transparent with low levels of suspended particles, phytoplankton, and dissolved organic matter. The decline in transparency of L. Tahoe over recent decades has been attributed to either increased nutrients (leading to a rise in phytoplankton biomass) or increased suspended sediments (leading to a rise in turbidity) or both. Public concerns about declining transparency have led to regulations to reduce nutrient discharge and plans to limit the entry of suspended sediments into the lake. The relative importance of nutrients and suspended sediments is still under investigation and it is likely that the relative impact of suspended sediments and phytoplankton on transparency vary over time. In the 1980's at Crater Lake a concern was also raised about the potential impact of sewage leakage on transparency of the lake. The response there was to reroute all wastewater out of the watershed and to initiate a long-term monitoring program. A review of over 100 years of Crater Lake data in 2007 suggested that transparency varied with decadal cycles in phytoplankton abundance of unknown cause (with a possible impact of UV-B in the 1980's from a decline in stratospheric ozone) and with infrequent large-runoff events from large summer storms that caused a transient increase in turbidity. In contrast to L. Tahoe, in Crater Lake an anthropogenic source of nutrients does not appear to be a management issue, while in both lakes the relative impacts of suspended sediments and phytoplankton on transparency vary over time.

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Significance of N and P co-limitation of phytoplankton growth in Lake Erie

The Lake Erie management paradigm has provided a successful strategy over the past 35 years, effectively controlling excessive growth of P-limited phytoplankton communities by preventing external loading of biologically available P; internal loading of P from anoxic sediments has been controlled by limiting the occurrence of large zones of hypolimnetic anoxia. Increasing evidence collected in our laboratory over the past ten years indicates that the premises on which the Lake Erie management paradigm is based no longer holds. Using a wide array of bioassay, chemical and biochemical indicators (nutrient amendment bioassays, SRP concentration, radiometric assay of phosphate uptake rate and turnover time, alkaline phosphatase specific activity, phytoplankton phosphorus-debt, and phosphorus deficiency index) we conclude that phytoplankton in the Central Basin of Lake Erie are N and P co-limited. Here we present data from summer 2008 that indicate this co-limitation; similar data taken from the Central Basin in 1996 show that phytoplankton communities were P-limited at that time.

We also show that nitrification, an oxygen-consumptive dissimilatory microbial process that oxidizes one mole ammonium to one mole nitrate whilst consuming two moles of O_2, exacerbates natural processes that lead to large regions of hypoxia and anoxia ("dead zones") in the hypolimnion of the Central Basin. Hypoxia and anoxia in turn support denitrification and anammox, two microbial processes that reduce nitrite ultimately to N_2, which leaves the lake by exchange with the air. That is, a major consequence of dead zones is that they inevitably lead to loss of available N, conceivably leading to N-limitation of phytoplankton. Lake Erie research needs to focus on the causes, controls and consequences of phytoplankton communities that are N and P co-limited. Management of Lake Erie ecosystem processes needs to broaden beyond looking only at loadings and consider also those processes that result in nutrient losses to the air. Management strategies also need to consider N dynamics as integral to understanding the limits of management capabilities.

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Characteristics and patterns of urban stormwater runoff into Lake Tahoe.

It is estimated that up to 30% of the nitrogen, 60% of the phosphorus and 50% of annual fine particulate sediment loads into Lake Tahoe derive from upland runoff sources, with most of that contributed by urban areas from around the Tahoe Basin. Stormwater monitoring since 2003, conducted as part of the Tahoe TMDL (Total Maximum Daily Load), has documented typical concentrations and event-loading characteristics from diverse land uses. A comparison of the five-year monitoring record at several urban sites is compared to runoff concentrations and loads from non-urbanized drainages. The median concentrations from the period of record for urban drainages at opposite ends of the lake were similar, with total nitrogen of approximately 1.5–2.0 mg N L^{-1}, total phosphorus of about 0.5–0.8 mg P L^{-1} and suspended sediment of 175–200 mg L^{-1}. The concentrations from non-urbanized drainages were less than urban concentrations by about two orders of magnitude, with lower runoff yields also contributing to substantially less loading. Similar analysis of the fine sediment concentrations and loadings from urban areas demonstrate equivalently high relative contributions of fine sediment particles to the lake. Plans for a regional stormwater monitoring program have been developed to assist in quantitatively tracking changes in the trends and patterns of urban loading rates with implementation of the Tahoe TMDL. These will be discussed in relation to runoff loading characteristics.

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Phytoplankton assemblage characteristics for Lake Tahoe, CA-NV, USA

Phytoplankton investigations at Lake Tahoe have been ongoing for many decades. Phytoplankton biovolume has been very consistent over time despite high interannual variation, indicating some stability in the system with respect to these algae. Chlorophyll concentration has also been relatively consistent over the >25 year period yielding very little information on the progressive degradation of the lake. At the same time there has been a ~2.5-fold increase in ^{14}C primary productivity. One potential explanation may be found in the picoplankton. Until recently, this component of the phytoplankton community had been overlooked. These small-sized cells (<2-3 µm) had not been identified and enumerated in older data sets. Picoplankton can make a significant contribution to primary productivity despite their relatively small size. Recent studies have suggested that picoplankton account for 35% of the total integrated phytoplankton carbon.

Even though the amassed data on phytoplankton indicate a stable system, those total community-based measures do not reflect changes at a taxonomic level. Among the major phytoplankton groups, chrysophytes have shown a significant downward trend based on monthly biovolume averages between the years 1982-2006. The other groups did not show a significant trend over the same time period. Some species and functional groups were favored in recent years and the lake's floristic shifts have been linked to individual species characteristics, which give cells a competitive advantage. Functionally, cells that are smaller, flagellated, or buoyant have been the most successful with increasing temperature and water column stability, while others were more strongly associated with changes in lake optics and system wide nutrient variability.

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The planktonic index of biotic integrity (P-IBI): A technique for linking ecosystem-based science to management in the Great Lakes of the world.

The planktonic index of biotic integrity (P-IBI) was developed and validated for Lake Erie during eutrophic (1970) and more oligotrophic conditions (1996) and then applied to several years of plankton data (1970, 1996-2004) in the lake. This technique uses plankton-based metrics (both phytoplankton and zooplankton) to assess lake ecosystem health. Because of the temporal variability of the plankton, analyses were conducted on a monthly (May-September) basis. During development, discriminant analysis was used to classify plankton community characteristics on the oligotrophic-eutrophic continuum (based on chlorophyll *a* and total phosphorus). Results showed that five plankton community metrics could distinguish among different trophic statuses during June, July, and August. The P-IBI has been used in management contexts as part of the Ohio Lake Erie Commission's *State of the Lake* (2004) and the binational (U.S. and Canada) State of the Strait's *Status and Trends of Key Indicators* (2007) report to communicate ecosystem health status to the public. Currently applications of this technique are being made to Lake Ontario's Bay of Quinte and Hamilton Harbour. Potential application of both the methodology used in the development of the P-IBI and the P-IBI itself to other great lakes of the world will also be discussed.

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Approaches to integrated assessment of large lakes involving new survey designs and synoptic, *in situ* technologies

The Laurentian Great Lakes have had, for decades, regular water quality monitoring programs to track conditions in their offshore waters, as dictated by a binational Great Lakes Water Quality Agreement between the US and Canada. Unfortunately, resources have limited monitoring to offshore waters, with coastal conditions largely ignored, and certainly not included in any regular, comprehensive monitoring program. Within the past decade we have been conducting an extensive set of studies as a foundation to incorporate nearshore and coastal ecosystems into potential lakewide survey designs. Coastal systems are dynamic and there is great spatial variability along the vast Great Lakes shoreline (~17,000 km, spread across the five main lakes); consequently, comprehensive programs to assess coastal conditions have been seen as costly and/or perhaps lacking in statistical power. Our coastal studies have emphasized an exploration of the influence of the character of coastal watersheds upon ecological conditions in adjacent coastal waters, and the linkages we have resolved help explain a great deal of the spatial variation in nearshore waters, from local to whole lake scales. This paper will summarize some insights and developments to date using powerful, coast-wide surveys with continuous *in situ* sensor sampling and a number of statistically-based study designs across the Great Lakes. We have made significant progress towards our goal of providing an approach to ecological assessment that integrates landscape, coastal and open lake processes in an efficient monitoring system for the basin.

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Dynamic simulation of basic physical, chemical, and biological processes of a large oligotrophic lake in Montana

We developed a simulation model of the large, oligotrophic Flathead Lake in Montana with the objective of examining the impact of regional development and especially of increased phosphorus loads on the plankton community. The model is driven by field-derived data on lake basin climate, nutrient concentrations and discharge rates of input rivers, and lake temperatures. It uses literature values for phytoplankton and zooplankton physiological and trophic parameters. Calculations are solved for one-meter depths with mixing. Sunlight intensity, wind, and thermal stratification also drive the model. Model runs demonstrated that wind-driven mixing rates proved better predictors of spring blooms than models relying on water column stratification. The model recreates the extensive empirical data on phytoplankton, zooplankton, and nutrients within ~20% for the four test years. A sensitivity analysis showed the model to vary by less than 40% within the range of studied coefficients. The summer biomass of phytoplankton in model forecasts is determined mainly by total nutrient concentrations. Zooplankton limit phytoplankton biomass more by making nutrients inaccessible by sequestering them in their bodies, rather than imposing grazing mortality. The model demonstrated the apparent importance of seasonal phytoplankton adaptation to low nutrient conditions. The model suggests that increased nutrient inputs from further basin development will result in more phytoplankton growth and loss of water clarity.

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Exploring the effects of climate change and spatial planning on habitats in Lake IJsselmeer, the Netherlands

In this study the effects of changes in water level regime on the ecology of Lake IJsselmeer were explored. Climate change and sea level rise affect safety, fresh water supply and nature in deltas. For The Netherlands, the Delta committee advised to raise the water level in the IJsselmeer up to 1.5 m in order to i) prolong gravity driven drainage of the lake to the Waddensea in case of sea level rise and to ii) increase the fresh water storage in case of extreme dry summers. The area of Lake IJsselmeer is of high national and international importance as a wetland. Therefore the effects of several water level regimes (differing in timing and in maximum and minimum water level) on ecology and the effects of compensating nature development options were explored using the tool HABITAT. HABITAT contains knowledge rules for ecological key processes in Lake IJsselmeer and uses abiotic and biotic factors to determine habitat suitability for species and ecotopes. The results show that due to the typical bathymetry of the lake (‘bathtub’ like because of the presence of dikes), an increased water level will lead to the diminishing of valuable shallow water areas and consequently to a weakening of important key elements in sustaining the area’s natural function. Compensating measures, such as sand nourishing, look promising and can reduce negative effects. The long-term effects of events such as low water levels caused by a high water demand should be investigated further and translated into knowledge rules to improve the analysis. In addition, water quality issues should be taken into account. However, HABITAT is a valuable tool to explore the effects of changes in environmental conditions due to climate change and spatial planning, thereby contributing to sustainable solutions.

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Environmental Management in the Lake Tanganyika Basin: Uniting Science, Politics, and Pragmatism in a Transboundary Monitoring Framework

Lake Tanganyika and its catchment basin are characterised by unique aquatic and terrestrial ecosystems, which are of major economic and environmental importance to the riparian countries of Burundi, Democratic Republic of Congo, Tanzania and Zambia. To identify and mitigate threats to the lake basin ecosystem, a series of focused scientific and participatory assessments were undertaken that led to the formulation of a Strategic Action Programme (SAP).

The SAP established transboundary priorities and sectoral interventions for the Lake Tanganyika basin that were endorsed by the riparian governments in 2000. It also identified national and regional mechanisms for implementing interventions, including the establishment of the Lake Tanganyika Authority (LTA), which is a management structure that embodies the four governments. Based on the recommendations from the SAP and recent knowledge on environmental threats, the LTA has prioritised interventions to mitigate the following threats: unsustainable fishing, pollution, deforestation and sedimentation, invasive species, and climate change.

To determine if interventions are effective, and to ensure that future management decisions are informed by scientific data, an effective environmental monitoring programme is essential. We are presently working towards the establishment of a programme to harmonise monitoring processes by adopting regionally agreed formats and parameters on which to collect environmental, biological, and socioeconomic data. Our objective is to: 1) Set up a sustainable monitoring system that enables high quality scientific data to be collected at low cost by local institutions; 2) Harmonize and Integrate this data at a regional level; 3) Translate data into management recommendations; and, 4) Ensure that regional management recommendations feed back into national interventions. We are tackling this challenge by closely involving local institutions as well as national government representatives and international research partners in the design of our monitoring programme.

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Cascading Impacts of Global Warming on Lake Victoria

Lake Victoria and Lake Tahoe share a common bond. They are both critical resources that contribute significantly to the economic productivity of their surrounding communities. These magnificent bodies of water supply fresh and clean water to the surrounding populations, are vital to sustaining agriculture and health of their respective regions, and are major tourist destinations that enrich the economies of their respective regions. Global climate change has the potential to severely impact the environmental health and economic sustainability of regions surrounding these and other great lakes of the world. Lake Victoria is already experiencing decreases in water supply, which has implications not only for the east Africa, but also for the Nile River basin. Significant loses in snowfall in the Sierra Mountains will decrease the quality and quantity of water required to sustain agriculture in the western United States. Innovative water-resource management, agricultural practices, policy-making are needed in both the United States and Africa to meet the challenges posed by loss of critical freshwater resources.

This paper will explore the secondary and tertiary effects that may arise in the Lake Victoria region as a result of the desertification due to climate change. Decreases in the availability and potability of water from Lake Victoria due to warming temperatures and decreased rainfall has already decreased agricultural productivity and increased disease outbreaks. If this continues unabated it has the potential to lead to mass migration, armed conflicts, and political instability. Mitigating these consequences requires integrated approaches that link environmental stewardship, agricultural management, and international security policy-making. Ties between ecosystem management and agricultural productivity around Lake Victoria will be examined in the context of anticipated changes in both the environmental and geopolitical climates. A framework for understanding and responding to the cascading impacts of climate change will be presented.

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The Science of Ecosystem-Based Management in the Great Lakes: Status, Progress and Emerging Issues

Lake ecosystems are our sentinels of environmental change and their effective management is one of our key planetary challenges in the 21st century. The evolution of ecosystem science as a basis for management is reviewed using the nested set of the Laurentian Great Lakes, Lake Ontario, and the Bay of Quinte as a primary focus. Other great lakes of the world, many of which are in Canada, provide a secondary focus. Ecosystem science has a long history in the Laurentian Great Lakes with developments driven in large part by the Great Lakes Water Quality Agreement, Lake-wide Management Plans, and Remedial Action Plans for Areas of Concern. By comparison most other large Canadian lakes have received little attention as is the case with many of the world's great lakes. The substantial arsenal of tools and knowledge accumulated in the Great Lakes can be applied elsewhere. As the range of ecosystem management problems has continued to grow, so the motivating theme has been shifting from restoration through rehabilitation and creation to adaptation now. The main emerging issue is the coalescing of the many stresses we have sought to manage singly: land use, population, habitat degradation, exploitation, invasive species, pollutant and contaminant loadings, and, finally, climate change. The essential features of effective ecosystem-based adaptive management are: monitoring, modelling, community engagement, sustainability, and decision-making. The last may prove the greatest hurdle as society becomes ever more divided and fractious given the global onslaught of environmental and societal challenges. The Great Lakes experience shows there is hope.

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Comparing the microbial - planktonic food webs of the Laurentian Great Lakes

Microbial - planktonic food web assessments of the Laurentian Great Lakes have been carried out by our laboratory for over 20 years. Structural and functional assessments showed that Lakes Superior, Huron and Erie were net autotrophic in the summer while Lake Ontario was net heterotrophic. Our determinations of "net autotrophy" and "net heterotrophy" were not based on community respiration experiments, but rather detailed microscopic analysis of the microbial and planktonic communities combined with radioisotope measurements of primary and secondary productivity. We also considered the health of these large lake ecosystems based on our assessment of the microbial food web and known stressors. Lakes Superior and Huron were found to be healthy ecosystems containing a large proportion of autotrophic carbon combined with high rates of picoplankton turnover relative to other phytoplankton and bacteria. Lake Erie, despite a plethora of known stressors, also fit this pattern, displaying considerable resilience. Lake Ontario was anomalous with a very high proportion of heterotrophic carbon combined with a high proportion of net plankton turnover indicating that the microbial - planktonic food web of Lake Ontario may not be generating enough energy to sustain itself and that the lake is likely under considerable stress. This study deployed a proven, robust methodology to examine and compare the microbial food webs of the Laurentian Great Lakes. The significance and implications of the microbial loop in the energy dynamics of large lakes is apparent.

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Trends in key fisheries on major lakes in Uganda: management options for sustainable production

Uganda's five major lakes including lakes Victoria, Albert and Edward which are transboundary waters; and lakes George and Kyoga which lie within her territory, are faced with major human induced and natural environmental challenges with resultant serious impacts on the fisheries ecology and related socioeconomics. These challenges include increased nutrient loading; increased siltation; decrease in water levels; eutrophication, increased occurrence of algal blooms; increased depth of anoxia; invasion and explosion of exotic aquatic weeds; introduction and explosion of non indigenous fish species; and loss of key fishery, ecological and evolutionary fish fauna. These challenges are compounded by the increased destruction of important ecotones and adjoined expanses of previously vegetated marshes for agricultural activities and settlement. Most notable consequences include the disappearance of nearly 200 cichlid fish species from the five major lakes; the extreme reduction in stocks of major native top carnivores including *Bagrus dogmac*, *Protopterus aethiopicus*, and *Clarius gariepinus* in these lakes in which Nile perch was introduced; and displacement and replacement of native tilapiines with introduced nilotic forms and those from elsewhere. The Nile perch, Nile tilapia, and 3 minnow-like cyprinids currently form the mainstay of fisheries in the country but more recently there has been a change in fortunes with the stocks of the introduced Nile perch in Lake Victoria negatively impacted by both environmental changes and heightened fishing pressure, while at the same time there has been a resurgence of a few of the pelagic cichlids species that had been reported as displaced and/or feared extinct from the major lakes. Of ecological significance, in addition to the five major lakes, is the availability of another 162 minor lakes that are relatively much smaller and several of them as satellites to the major lakes where they form groups/complexes of lakes around each of the major lakes. The key attributed of these lake complexes is their contained diverse and radiant fish fauna most of which are endemic to these waters, and do retain a sizeable resemblance of fish fauna diversity that was previously recorded in the major lakes. This paper proposes development of specific comprehensive resource management plans for the various lakes complexes with associated species and/or species complexes specific management strategies to stem the impact of highlighted environmental and ecological challenges facing Uganda lakes.

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Genetic Biodiversity and Management of Inland Fisheries: Options for Management of the Cichlid Fauna of the Lake Victoria Region

Several factors have had a severe negative impact upon both the aquatic species diversity and overall genetic diversity within the inland fisheries of Africa. Environmental degradation has usually resulted in reductions of population sizes, often resulting in local or even widespread extirpation of populations. Populations have frequently become fragmented and genetically isolated because of alterations in habitat. Introductions of exotic species have been poorly conceived and often have resulted in unforeseen ecosystem-wide problems. Environmental changes resulting from competing human uses have degraded habitats, altering nutrient availability and turbidity, while several introduced exotic species have had severe negative effects on the native fauna through predation, competition and hybridization. The history of species changes in the Lake Victoria Region (LVR) of east Africa provides examples of all these processes. The LVR comprises five large lakes, Victoria, Kyoga, Edward, George and Kivu, with similar species groups which radiated into forms endemic to specific lakes. We present the results of 10 years of study on speciation and evolution in short evolutionary time. Evolutionary patterns have been repeated numerous times in the LVR, sometimes by evolutionary parallelism, sometimes from seemingly improbable dispersal events. The complexity of the lakes themselves offer options for conservation of cichlid fishes through development of lake specific resource plans, potentially utilizing satellite lakes as isolated refugia for key ecological and evolutionary species. For these threatened key species, including many displaced and near extinct cichlid fishes, supportive nursery propagation of juvenile stages collected from the wild, and eventual release into satellite lakes managed for conservation of these key species, offers the possibility of an immediate reprieve. Such augmentation to natural recruitment should strengthen the ecological status of these key species. If coupled with relevant policies, this should lead to protection of many more species than currently being considered. There is a need to refocus the fisheries management objectives in the LVR to include conservation of species that may not be economically important, but play key ecological and evolutionary roles. Integrated resource management and species specific survival plans must be a priority.

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The Global Threat of Invasive Species to Large, Freshwater Lakes: the Laurentian Great Lakes as an Example

The introduction and spread of invasive species are among the most important and pervasive threats to the integrity of freshwater lake ecosystems worldwide. Because of increased global trade between continents, and the removal of natural barriers within continents, the ability of species to spread beyond their native ranges has been enhanced. While most introduced species have little ecological impact, the literature is rich with examples of how the introduction of just a single, well-suited, prolific species has fundamentally changed the biodiversity, food web structure, and energy/nutrient pathways of a given water body. Once such a species is established, elimination is nearly impossible and impacts not easily reversed. While ecologically-damaging invasives range from aquatic plants to fish, perhaps the most profound and far-reaching changes to lake ecosystems have been associated with the introduction of filter-feeding bivalves. The Laurentian Great Lakes provide a good example. There are over 180 non-indigenous species documented in the Great Lakes, and many of these such as the sea lamprey and alewife have caused broad changes in ecosystem function. Yet the introduction of the filter-feeding dreissenids, *Dreissena polymorpha* and *Dreissena rostriformis bugensis*, over two decades ago has changed, and continues to change, all aspects of the Great Lakes ecosystem. In nearshore regions, these species have extirpated native mussels from open waters, increased water clarity, altered nutrient flow patterns, and shifted primary production from pelagic to benthic regions. Some consequences have been the proliferation of the nuisance benthic macroalgae *Cladophora*, and blooms of toxic cyanobacteria. In offshore regions, the important spring bloom of diatoms is no longer apparent, and native invertebrate species that serve as food for preyfish in offshore regions have dramatically declined or disappeared. As a result, fish populations have declined, leading to poor growth and condition of stocked salmonids.

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Nonnative largemouth bass (*Micropterus salmoides*) in Lake Tahoe: movement, potential for establishment, and predation impact

Nonnative species introductions and their establishments are of growing concern due to their potential economic and ecological impacts. Nonnative largemouth bass *Micropterus salmoides* is examined prior to its widespread establishment in Lake Tahoe. Currently a single sustaining population is found in the Tahoe Keys (a large-scale marina located in the south end of Lake Tahoe), however, lake-wide colonization can take only several years and is promoted by the warming climate and habitat modification through introductions of other nonnative species such as plants. Lake-wide establishment of these predators may significantly impact the native biota of Lake Tahoe. In order to facilitate the development of appropriate management strategies to prevent and control lake-wide proliferation of these fish, we 1) examined their potential spreading mechanism and their overwinter behavior using hydroacoustic telemetry, 2) developed an "establishment likelihood" model comprised of two data layers (nearshore temperature and distribution of preferred habitat structure) at ~2 km resolution, and 3) estimated their consumption impact on native forage fishes using a bioenergetics model. Tracking data reveal that largemouth bass are potentially leaving Tahoe Keys and may move to other parts of the lake given suitable conditions. Data collected over the winter months show localized movements. The establishment model suggests that the entire nearshore is thermally suitable for bass spawning, and that current and future bass establishment is likely limited by the distribution of aquatic vegetation. Dependent on bass densities, bioenergetics model-derived consumption estimates compared to nearshore fish biomass estimates indicate that bass can eliminate 100% of nearshore fish biomass at 37-80% of sites examined. This is the first comprehensive study in Lake Tahoe to predict future distribution and potential ecological impact of a nonnative species. Our approach can assist managers in prioritizing areas for control and management of largemouth bass.

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Particle size distribution in lakes of varying geology, watershed size, and urban development: Fine particle sources and implications for management

Fine particles have been shown to exert an influence on water quality that is disproportionate compared to their mass contribution expressed as fraction of total suspended solids. Consequently, interest in methods for quantifying concentrations and size distributions of these particles has increased. The recent availability of high sensitivity laser diffraction instruments for measurement of fine particles in natural waters has enabled assessment of the dynamics of these particles on fine spatial and temporal scales.

Interest in fine particle size distribution (PSD) depends on the management focus in the system of study. At Lake Tahoe, CA-NV, USA, fine particles are the basis of the Total Maximum Daily Load (TMDL) for clarity and monitoring these particles is therefore essential for meeting water quality management goals. At Lake Biwa, Shiga Prefecture, Japan, management is focused on oxygen depletion in the benthic boundary layer (BBL) at the lake bottom. Oxygen concentration at the lake bottom is closely linked to lake stratification, internal wave dynamics, and sediment resuspension. Measuring the PSD is therefore necessary for addressing the management goals there. In more remote lakes, such as Crater Lake, OR, USA, PSD measurements provide information about the geology of the basin and characteristics of the watershed.

In this study, PSD measurements from two North American lakes (Lake Tahoe and Crater Lake), four lakes in Chilean Patagonia (Lake Plomo, Lake Negro, Lake Cochrane and Lake Bertrand) and one lake in Japan (Lake Biwa) are compared and analyzed for clues about the source of the fine particles found in each distribution, the characteristics of the lakes' watersheds and underlying geology and the impact of urbanization on lake water quality. In-situ laser diffraction is an extremely useful tool for measuring PSD's in natural waters and can provide necessary information for addressing a host of lake water quality management problems related to fine particles, sediment transport in addition to biological productivity.

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The invasive macrophyte *Elodea canadensis* in Lake Baikal and the watersheds of the Arctic and Pacific Oceans

A native to North America, *Elodea canadensis* first arrived in Western Europe in 1836. It has spent much of the last two centuries expanding its range east across Northern Eurasia. Recently, it completed its expansion from the Atlantic to the Pacific when it crossed the final continental divide and was recorded in the Amur River Basin. The spread of *E. canadensis* in Russia originated in three areas: a) St. Petersburg (Neva River in 1881-1882) – facilitating expansion to the European part of the Russian Empire, which included modern Finland, Poland, and the Baltic states; b) The Ural Mountains (Yekaterinburg in 1892) - facilitating expansion to the watersheds of Western Siberia and Northern Kazakhstan; and c) Angaro-Baikalsk (Irkutsk in 1970) - facilitating expansion from the Irkutsk Reservoir to the Angara River, from there downstream to the Yenisei River, and upstream into Lake Baikal and the Selenga River. This final introduction also allowed it to penetrate into the hydrologically distinct watersheds of the Lena (in 2001), and the Amur (in 2009). In accordance with the objectives, the main results of this study are: 1) documentation the historic expansion of *E. canadensis* in Northern Eurasia with an emphasis on the invasion of Lake Baikal; 2) Documentation long-term changes in the biomass of *E. canadensis* in Chivirkusky Gulf (Lake Baikal) as well as in Lake Kotokelskoye, and Lake Shutshie; 3) Assessment parameters of the ecological niche of *E. canadensis* in its new habitat; and 4) Identification of invertebrate species that inhabit the invasive flora.

Investigation was partially supported by the grants: RFBR №08-04-98034_r_Siberia_a, and the Program “Biological diversity” (Project R 23.10) of the Russian Academy of Sciences.

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Development of Numeric Load Reduction Targets for Lake Tahoe, CA-NV, USA

Lake Tahoe is world renowned for its natural beauty and cobalt-blue color. However, long-term monitoring shows that Secchi depth has declined by 10 m since 1968. This is attributed to the influx of phosphorus, nitrogen but especially fine sediment particles <16 μm in diameter. These pollutants come from land disturbance and urbanization (including roadways and road maintenance) and are accompanied by a loss of natural landscape capable of treating runoff. Efforts to improve lake clarity focus on science-based restoration plans (e.g. Lake Tahoe TMDL). This program (1) quantifies fine particle and nutrient loading from urban runoff, vegetated upland flow, atmospheric deposition, stream channel/shoreline erosion and groundwater, (2) uses a customized Lake Clarity Model to link pollutant loading to lake response, and (3) develops the framework for a plan to achieve an annual average Secchi depth of 30 m as required by existing regulations.

Fine sediment particles comes primarily from the urban setting (72% of total), while 55% of the nitrogen comes from atmospheric deposition, and 39% and 26% of the phosphorus from urban and non-urban runoff, respectively. The Lake Clarity Model shows that the 30 m target can be achieved if nutrients and particles from all sources are reduced by 55 percent or with a 75 percent reduction from just urban sources. Based on a pollutant reduction opportunities analysis for the Tahoe basin, the *Clarity Challenge* (24 m Secchi depth within 15 years) can be met by a reduction of 32%, 14% and 4% for particles, P and N, respectively. The results from paleolimnological research and an empirical Secchi depth versus particle relationship suggest that Lake Tahoe can improve once loading is reduced. A model simulation where all fine particles from urban source are set to zero results in a 31 m Secchi depth which resembles the hypothesized historic baseline.

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Atmospheric Deposition of Nitrogen and Phosphorus to Lake Tahoe, CA-NV, USA

Because of the large surface area of Lake Tahoe (501 km^2) in comparison to its drainage area (812 km^2), it is reasonable to expect that nutrient loading by means of atmospheric deposition directly to the lake surface is important. While evidence in support of this hypothesis was first published by Jassby *et al*. (1994), additional studies were considered necessary to reduce uncertainty. Dry deposition was estimated by (1) direct capture in deposition buckets (land- and buoy-based) and (2) coupling ambient air measurements with deposition models. Wet deposition was measured with deposition buckets.

Total N load per year over the entire lake surface was significant at 218 metric tons (MT) representing 55% of TN inputs from all external sources. The ratio of dry:wet TN deposition was 2.5:1. Dissolved inorganic loading (as nitrate plus ammonium) was 148 MT or 68% of TN with a dry:wet ratio of 3.6:1. This accounted for nearly 80% of DIN loading from all external sources. Dissolved organic-N comprised 28% of the TN pool with similar dry and wet annual loading values. When expressed on an areal basis (g N m^{-2} yr) the N-deposition for Lake Tahoe agreed well with values from other mountainous regions in the western United States. N-deposition over the lake away from the shoreline was half that measured at a land-based deposition station.

Total phosphorus deposition to the lake surface was on the order of 7.0 MT, accounting for 15% of P-load from all external sources. Soluble reactive-P accounted for 2.3 MT or about one-third of the TP. Areal deposition rates at Lake Tahoe were close to a world-wide median of reported values. Road sand and terrestrial dust have been shown to be the major contributors to atmospheric-P. The high ratio of N:P in atmospheric deposition is considered the cause for a shift from N-P co-limitation to a current condition of primarily P-limitation in Lake Tahoe phytoplankton.

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Modelling urbanization effects on Lake Titicaca

The Lake Titicaca basin is one of the most impoverished areas in Latin America. The World Bank is supporting the government of Bolivia to improve living conditions through stimulation of sustainable development. The two main municipal sources of contamination of Lake Titicaca are the cities of El Alto in Bolivia, with a population of over one million, and Puno in Peru, with a population of about 100,000. El Alto has a lagoon wastewater treatment plant whose effluent is discharged to a water course that conveys it, along with other untreated wastewaters, into Lake Titicaca at Cohana Bay. Other smaller towns have no treatment plants and their wastewaters enter the lake directly. The main effect of these wastewaters is eutrophication due to nutrients. The wastewater treatment processes do not remove Nitrogen and Phosphorous, so they do little to diminish nutrient impacts, and it is unlikely that nutrient removal will be implemented in the near future. So the proposed strategy is to minimize municipal discharges from entering the lake by treating and reusing them for irrigation using Stabilization Reservoirs. The nutrients then become an asset. However, El Alto is not part of the project, and for the small towns located on the lakeshore, preliminary treatment followed by discharge from outfalls that rapidly dilute and disperse the effluent are proposed. This will not eliminate nutrients, however, and mathematical modeling is needed to ensure that the nutrient loads, along with well designed, effective outfalls will prevent eutrophication and any other detrimental environmental impacts. In this paper, we discuss the pollutant sources and their effects and the dynamics of mixing in the lake and present the results of mathematical modeling used to ensure that the project will preserve the quality of the lake's water.

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Lake Tahoe Interagency Monitoring Program – An Integral Part of Science in the Lake Tahoe Basin

The Lake Tahoe Interagency Monitoring Program (LTIMP) is an essential part of integrated science in the Lake Tahoe Basin. LTIMP stream monitoring began in 1979 after interagency negotiations and collaboration. The current monitoring program began in 1988 as a cooperative program between the U.S. Geological Survey (USGS), Tahoe Regional Planning Agency (TRPA), and University of California, Davis - Tahoe Environmental Research Center (UCD-TERC). The U.S. Forest Service (USFS) has provided additional funding. Since 1988, more than 10,000 water-quality samples have been collected and analyzed at a cost of more than $11 million dollars.

The objective of the monitoring program is to collect long-term water-quality and flow data on streams tributary to Lake Tahoe. These data are used for: 1) estimation of suspended sediment and nutrient loads and trends from major and minor tributary streams from both disturbed and undisturbed basins, 2) assessment of the effects of changing land use on water quality, and 3) supporting basic research.

The current monitoring program consists of 18 sampling sites on 10 major and minor tributary streams around Lake Tahoe. The monitoring program follows three sampling schedules; systematic monthly sampling, storm sampling, and intensive snow-melt runoff sampling. Water samples are analyzed for nitrogen and phosphorus species and suspended sediment concentration. Continuous streamflow data are collected at all of the 18 sampling sites. The water-quality and streamflow data are published in the USGS Nevada Annual Data Report and are available from the USGS National Water Information System (NWIS) website (http://waterdata.usgs.gov/nv/nwis/nwis).

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Water Quality of Deep Lakes in Response to Climate Change

Meteorology exerts a large influence on a lake's internal heating, cooling, and mixing, which, in turn, affects important features of lake water quality and ecology. Records spanning the last 40 years show that the Lake Tahoe completely turns over once in every three to four years during winter. Full mixing homogenizes the entire water column. Deep mixing not only supplies dissolved oxygen to the hypolimnion but also alters the distribution of suspended fine particles and nutrients below the photic zone. Records show that Lake Tahoe volume averaged water temperature has increased approximately 0.13 ^{o}C per decade and the resistance of the lake to mixing has concomitantly increased. Therefore, the objectives of this study are to (1) estimate scenarios of the future weather variables at fine resolutions (approximately 12 km × 12 km) using predictions of Global Climate Models (GCMs), and (2) simulate thermodynamic and water quality properties of the lake for the period 2001 to 2098 using calibrated Lake Clarity Model (LCM).

Predictions of two GCMs: Geophysical Fluid Dynamics Laboratory and Parallel Climate Model predictions for the A2 and B1 scenarios were downscaled to approximately 12 km × 12 km resolution. Biases in the downscaled data were corrected before using in the model. The 98-year simulation results show that (1) there is pronounced changes in deep winter mixing, spring stratification, and dissolved oxygen patterns and (2) prolonged reduced mixing (>10 years) result in anoxic condition at the bottom releasing significant amount of ammonia and soluble reactive phosphorus from sediments.

Deep mixing after a prolonged period of anoxia at the bottom will release significant amount of nutrients from sediments to the photic zone resulting in water quality changes. Thus, current lake management strategies should be integrated with new approaches and methodologies in order to address the water quality problems associated with climate change.

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Physical Limnology's Role in the Distribution and Spread of Invasive Species in Lake Tahoe

The spread of invasive species such as Asian clam (*Corbicula fluminea*) in Lake Tahoe is largely controlled by transport and mixing processes within the lake. The extent to which these processes can be understood will assist in the early discovery and effective control of invasive species. Since the discovery of Asian Clam in Lake Tahoe in April, 2008, a broad range of measurement and modeling techniques have been applied, in combination with ongoing, long-term monitoring programs, to better understand the distribution and spread of invasive species. Using a combination of satellite tracked drogues, *in situ* acoustic Doppler current profilers, autonomous underwater vehicles, high resolution thermistor chains and three-dimensional numerical models, the expected trajectories of planktonic stages of invasive species in Lake Tahoe can be described. While efforts to prevent the introduction of invasive species remain paramount, once present in the lake it is the responsibility of management agencies to best control their spread. In part this requires a predictive ability afforded by field-validated hydrodynamic models, and in part it requires an understanding of how specific organisms are transported and the conditions under which they can reproduce and grow.

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Contributions towards an ecosystem based management of Lake Titicaca basin

The paper will describe and analyze the public policies implemented around Lake Titicaca in the last 4 years and how these policies may have contributed in achieving an ecosystem approach to Lake Titicaca management. Special emphasis will be given to explain the interaction between aquaculture development policies and policies directed at conserving the native species. The implementation of these policies is framed by a complex interaction of institutional relations. The role of scientific institutions and their studies along this interaction will be at the centre of our analysis.

Since 2007, the Peruvian government and the Spanish Agency for International Development Cooperation (AECID) have been carrying out, in association with a complex network of local, regional, social and economic stakeholders, the *Programa de apoyo a la pesca artesanal, la acuicultura y el manejo sostenible del ambiente*-PROPESCA (Programme to support small-scale fisheries, aquaculture and the sustainable management of the environment). This program has emphasized the sustainability and competitiveness of Lake Titicaca's fisheries and aquaculture sector. The program combines both development and research aimed at further understanding of the lake's ecology and its ictic native resources (ispis, mauri, boga or suche).

Several national and international scientific institutions have carried out different research projects within this program. Examples of these include: the genetic characterization of native species, water quality monitoring programs and construction of an adequate legal framework for the exploitation of the lake's natural resources. The results of these studies have nourished the national and regional policies about the lake.

However, the extent of this scientific impact in the lake's management policies has been limited. Internal institutional weakness and fragile integration of the diverse management perspectives among different stakeholders are narrowing the implementation of an ecosystem approach to Lake Titicaca´s management.

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Groundwater is an Important Source of Nutrient Loading to Lake Tahoe, CA-NV, USA

Lake Tahoe's renowned scenic beauty is strongly linked to the lake's extraordinary clarity, which has been declining at a rate of about 1 foot per year since the first clarity measurements were taken in 1968. The influx of nutrients and fine (<16 μm in diameter) sediment to the lake are responsible for this decline in clarity. Groundwater plays an important role in nutrient loading to the lake. Annual groundwater flow directly into the lake is about 50 to 60 million m^3/yr. Approximately, 15% of the total nitrogen and 10% of the total phosphorus load entering Lake Tahoe is from groundwater inflow. Groundwater also plays an important role in nutrient loading to streams in the basin because at least 40% of stream flows entering Lake Tahoe originate as shallow groundwater. Fine sediment entering the lake is primarily from stormwater runoff, but as more stormwater is captured and infiltrated to shallow groundwater zones, the colloidal material in groundwater may potentially contribute significant additional fine particles and nutrients to the lake. Nutrient concentrations in groundwater entering the lake are highest in urbanized areas around the lake, where nutrient loading from groundwater affects the near shore environment, particularly in regard to algal growth.

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Is the ecosystem approach the way forward for Lake Victoria's fisheries?

Research in Lake Victoria dates back to the 1920s, thereafter, several studies have been carried out to assess the status of fish stocks and the health of the lake. Several governance policies based on this research have been formulated and implemented. For example, due to decline in catches, a minimum mesh-size of 5'' was enforced to protect the endemic tilapiines (*Oreochromis esculentus* and *O. variabilis*) in the 1930s. This was reduced to 4.5'' in the early 1950s in order to catch the smaller species of *O. variabilis* and elephant fishes (momyrids). A further decline of catches in the 1960s led to the removal of mesh size restrictions to harvest underexploited cichlids (haplochromines) and a small cyprinid (*Rastrineobola argentea).*

Independence of the three riparian states of Kenya, Uganda and Tanzania in the 1960s led to the formulation of different national research objectives, policies and management structures. Some of the management measures included; enforcement of different mesh sizes for *R. argentea,* closed seasons and restricted areas. Even with new regulations, the health of the lake deteriorated and fish catches continued to decline. The riparian states realized that for sustainable exploitation and conservation of the lake, an ecosystem approach to its fisheries had to be applied.

Formation of the East Africa Community (EAC) in 1994 designated Lake Victoria and its basin as an "area of common economic interest" and a "regional economic growth zone", which has to be developed jointly by the Partner States. Bodies of EAC such as the Lake Victoria Fisheries Organization \and the Lake Victoria Basin Commission were tasked with applying an ecosystem approach to Lake Victoria's exploitation.

This paper discusses some of the major regional policies with respect to the management of Lake Victoria's resources based on science, their failures and why the ecosystem approach could be the way forward.

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Status of fisheries management on Lake Tanganyika

In the year 2000, a Framework Fisheries Management Plan for Lake Tanganyika was produced but then shelved for the next ten years. This implies that the exploitation of fisheries of the lake was not a priority. It should be taken into account that two of the lake's riparian countries went through periods of civil strife and unrest. Furthermore all four countries bordering the lake had to deal with Internally and Internationally Displaced People. Fisheries statistics are incomplete or non-existent. Biomass estimates date back to the previous millennium and in the interim, a change in fish migration took place which could be linked to climate change. Many changes occurred in the fisheries during the past two decades, but little attention has been paid to managing or controlling it. Socio-economic surveys yielded information that newcomers (returning refugees) into the fisheries cannot be refused and therefore the fishing effort continues to increase. The four governments are conscious of the problems but find it difficult to take proper action, despite the regional initiative to start up a fisheries assistance project, as part of a wider development intervention. In cases where insufficient manpower is preventing implementation, then the countries should resort to involving the local communities. The question remains whether the same system should be adopted as in place on Lake Victoria. This paper reviews the existing means for fisheries management and discusses a formula for community involvement in managing the fisheries resources of Lake Tanganyika.

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Asian clam (*Corbicula fluminea*) invasion in Lake Tahoe: The ecology and management of an invasive bivalve in an oligotrophic lake

The invasive Asian clam (*Corbicula fluminea*) is established the littoral zone of Lake Tahoe, CA-NV. *C. fluminea* was first observed in Tahoe in 2002, and by 2009, high density populations (up to 6000/m^2) have been observed in the southeast region of the lake, where it has negative impacts on benthic diversity and is associated with filamentous algal blooms of *Zygnema* sp. and *Cladophora glomerata*. As part of a study of the ecology and lakewide distribution of *C. fluminea*, benthic samples were collected every 6-8 weeks from October 2008 through April 2010. *In situ* growth experiments are used to estimate the abundance and growth of the *C. fluminea* population and track cohort growth rates. Widely distributed (2-70 m water depth) along Lake Tahoe's well-oxygenated littoral zone, *C. fluminea* maximum size and life expectancy is lesser in this subalpine, oligotrophic ecosystem, but growth rates and population densities are similar and can exceed those in warmer, more nutrient-rich ecosystems. Despite the observed high densities, *C. fluminea* populations are not exhibiting density dependence and range expansion continues within the lake with long distance dispersal events. Experimental efforts to manage new populations using two non-chemical strategies (diver assisted suction removal and bottom barrier application) are currently underway. Diver assisted suction removal is effective at reducing *C. fluminea* as well as native macroinvertebrate communities. However, recolonization of these plots occurs, and financial costs are high. Bottom barrier application resulted in 100% *C. fluminea* and 70-95% benthic macroinvertebrate mortality after a 28-day period from August to September 2009. A cost and feasibility analysis of large-scale bottom barrier application in Tahoe is under consideration.

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Notes

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AEHMS Global Action Plan: 2010-2011

Exploring Great and Large Lake Ecosystems of the World (EGLLE) - *SIL Congress*	*August 15-20, 2010*	*Cape Town, South Africa*
Integrating Ecosystem Health, Toxicology and Management: *Can laboratory and field be linked? - 37th Aquatic Toxicity Workshop*	*October 3-6, 2010*	*Toronto, Canada*
ECOSEAS – Managing Ecosystem Health of Tropical Seas: *Environmental Management in Coastal Ecosystems*	*October 19-21, 2010*	*Kuala Lumpur, Malaysia*
GULF II – The State of the Gulf Ecosystem: *Functioning & Services*	*February 8-10, 2011*	*Kuwait*
AEHMS 10, Changing Aquatic Ecosystems: *Health, Integrity, and Adaptive management*	*June 13-15, 2011*	*Siena, Italy*

Aquatic Ecosystem Health and Management Society

AQUATIC ECOSYSTEM HEALTH & MANAGEMENT

The official Journal of the Aquatic Ecosystem Health & Management Society

A peer reviewed international journal published quarterly which is devoted to understanding ecosystem performance, function and management from integrated, multi-disciplinary and sustainable perspectives.

The major objective of the Journal is to promote an understanding of the structure, function and performance of healthy and damaged ecosystems (freshwater, marine, estuarine) from integrated, multi-disciplinary and sustainable perspectives. The Journal focuses on the development and application of management practices that will protect, maintain or restore the health of ecosystems.

The AEHMS recognizes the need to explore the complex interactions between human society, ecology, economy/development, politics and the environment. It also encourages a watershed approach, acknowledging that aquatic ecosystems are influenced by atmospheric and terrestrial processes, both natural and anthropogenic.

The Journal provides a forum for the assessment and discussion of ecosystemic, integrated approaches to aquatic ecosystem research and management. This includes concepts and approaches that address health, integrity, performance, efficiency, remediation, restoration recovery, conservation, sustainable human use and development. This Journal seeks to foster international and cross-sectorial exchange of information among scientists, academicians, managers, engineers, doctors, lawyers, citizens, business, industry, politicians and governments on the health and sustainability of global aquatic resources.

Scope:

Aquatic Ecosystem Health & Management (AEHM) will publish:

- peer-reviewed original papers
- state of the art reviews and critiques on current issues
- invited perspective essays
- short, communications dealing with concepts, techniques and ideas warranting rapid publication
- special issues devoted to selected themes, approaches, ecosystem types and ecotechnologies

Representative Topics:

- Integrated and ecosystemic approaches to management
- Assessment of the effects of the onset and cessation of anthropogenic perturbations on the health and integrity of food webs
- Bioassessment/biomonitoring techniques, protocols and other diagnostic tools that enhance the understanding of the ecosystem performance, resilience, response and recovery processes
- Development and modification of early warning indicators and diagnostic methods for a better understanding of ecosystem health, resilience, functioning and evaluation of management practices
- Development of environmental and habitat guidelines, aquatic quality guidelines, remedial actions, innovative management strategies, and monitoring protocols for the restoration of impacted ecosystems and the maintenance of healthy systems
- Evaluation of the cumulative effects of large scale perturbations and activities such as damming, dredging, river diversions and water transport
- Technologies for the reclamation of highly-damaged or poorly-utilized areas including war-affected regions
- Application and integration of various disciplines such as ecology, toxicology, limnology, fisheries, statistics, modeling and environmental risk assessment towards the assessment of ecosystem health.

"The Instructions for the Preparation of the Manuscript" can be found at www.aehms.org.
Manuscripts should be submitted to:

Dr. M. Munawar, Chief Editor
Fisheries and Oceans, Canada Centre for Inland Waters, 867 Lakeshore Rd., P. O. Box 5050
Burlington, Ontario, Canada. L7R 4A6
mohi.munawar@dfo-mpo.gc.ca

Special Issues of the *AEHM*	Volume	Year
Assessing Great and Large Lakes of the World (GLOW V, Part II)	Vol 13(2)	2010
Changing Great Lakes of the World and Rift Valley Lakes: Sustainability, Integrity and Management (GLOW V)	Vol 13(1)	2010
Ecosystem sustainability & health of threatened marine environments (ESHTME)	Vol 12(4)	2009
The State of Lake Huron: Ecosystem Change, Habitat and Management, Part II	Vol 12(1)	2009
Checking the Pulse of Lake Ontario	Vol 11(4)	2008
State of Lake Huron: Ecosystem Change, Habitat, and Management, Part I	Vol 11(2)	2008
Changing Great Lakes of the World (GLOW IV)	Vol 11(1)	2008
Great Lake Victoria Fisheries: Changes, Sustainability, and Building Blocks for Management	Vol 10(4)	2007
The State of the Gulf Ecosystem: Future and Threats	Vol 10(3)	2007
Freshwater fishes of South America: Their biodiversity, fisheries and habitat	Vol 10(2)	2007
Sediment Quality Assessment: Watershed-Sediment Management from Source to Sink	Vol 10(1)	2007
Aquatic Ecosystems of Malaysia: Health, Sustainability and Management	Vol 9(2)	2006
Aquatic Ecosystems of China: Concerns, Technologies and Management	Vol 9(1)	2006
Aquatic Ecosystem Health: Scaling from Local to Global Perspectives	Vol 8(4)	2005
The Great Himalayas: Ecology, Health and Management	Vol 8(3)	2005
Assessing Risks and Impacts of Contaminants in Sediments (Continuation of papers from SQA5, Issue 7:3, 2004)	Vol 8(1)	2005
Emerging Issues in Lake Superior Research	Vol 7(4)	2004
Assessing Risk and Impacts of Contaminants in Sediments	Vol 7(3)	2004
Coastal Wetlands of the Laurentian Great Lakes: Health, Integrity and Management	Vol 7(2)	2004
Comparing Great Lakes of the World	Vol 6(3)	2003
Barometers of Aquatic Ecosystem Health and Integrity	Vol 6(2)	2003
Freshwater Biodiversity in Australia	Vol 6(1)	2003
Great Lakes of the World: Food Web, Fisheries, and Management	Vol 5 (3)	2002
Resilience and Integrity of Aquatic Ecosystems	Vol 5 (1)	2002
Freshwater Fish Habitat, Science and Management: A Global Perspective	Vol 4 (4)	2001
Aquatic Ecosystems of Tropical and Temperate Regions: Health and Management	Vol 4 (3)	2001
State of Brazilian Aquatic Ecosystems	Vol 3 (4)	2000
Ecosystem Health of Lake Baikal, Russia	Vol 3 (2)	2000
Large Lakes of the World: Comparative Ecology	Vol 3 (1)	2000
Sediment Quality Assessment: Tools, Criteria and Strategies	Vol 2 (4)	1999
Jack Christie Memorial Essays	Vol 2 (3)	1999
Integrated Toxicology	Vol 2 (1)	1999
Mexican Waters: Ecology Health and Management	Vol 1 (3-4)	1998
Managing Aquatic Ecosystems in Southern Africa	Vol 1(2)	1998

Ecovision World Monograph Series

Dr. M. Munawar, Series Editor

An International, integrated, peer reviewed and scientific publication

Exploring the linkages between society, ecology, ecosystems and the environment

Objectives:

The Ecovision World Monograph Series has been launched to focus on the paradigm of life on our ever-changing planet and its sustainability under the impact of physical, chemical, biological, and human influences. It covers detailed and comprehensive treatments of various topics, subjects and ecosystems. The Ecovision Series is dedicated to integrated and ecosystemic research merging the high quality of a journal with the comprehensive approach of a book.

Scope:

- Ecovision Series will publish peer-reviewed groups of original papers in a book form on specific topics, themes, issues, subjects, concepts, or ecosystems.
- It promotes an ecosystemic, multi-disciplinary, multi-trophic, and integrated approach.
- The Series focuses on the integrity, health, restoration, remediation, and management of stressed ecosystems.
- It encourages publications dealing with the effects of environmental perturbations on ecosystem health at the structural, functional, and ultra-structural levels.
- It publishes material dealing with the integrated assessment of environmental issues, involving interactions between air, water, land and human health.
- The Series fosters trans-disciplinary and cross-sectoral linkages between the environment and ecological, socio-economic, political, ethical, legal, cultural, and management considerations.

Themes and topics:

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- Comparison and management of large ecosystems, such as Great Lakes of the World (GLOW) and marine ecosystems with emphasis on food web dynamics
- Ecosystem health of stressed habitats such as harbours and embayments
- Effects of pollutants of global interest, such as metals, organic contaminants, and petroleum hydrocarbons
- Effects of large-scale practices, such as the damming and diversion of rivers, and deforestation
- Sampling, monitoring, analytical, bioassay, and other assessment techniques, including statistical and modelling approaches
- Ecotechnologies designed for the recovery, restoration, rehabilitation, and integrated management of perturbed ecosystems. Also those designed for the "reclamation" of poorly-utilized areas such as deserts
- Integrated toxicology
- Risk assessment and ecosystem modelling
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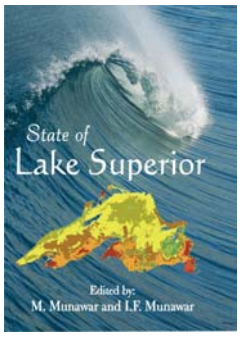
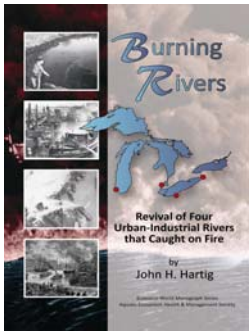


State of Lake Superior

(2009. 705 pages, 157 figures, 60 tables, indices)

This volume offers a polythetic view of current conditions in Lake Superior and some insightful suggestions about where and how improvements should continue. The chapters presented range from basic reviews of what we know as a consequence of effective research, to those that identify the little we know about challenging environmental issues for the future. Among those are the continuing concerns about contaminants, the burgeoning march of invasive species and the portent of global change. We find some encouragement in the resilience of this large lake ecosystem. There is credit and hope reflected in our abilities to guide both the continuing restoration and effective protection of Gitche Gummee, the world's largest lake.

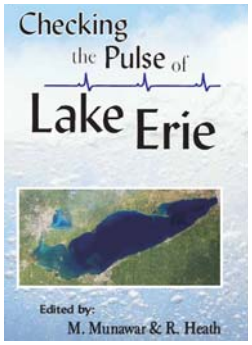
- J.F. Kitchell, Director, Center for Limnology, University of Wisconsin.



Burning Rivers

(2010. 180 pages, 43 figures, 17 tables, indices)

It has been 40 years since the Buffalo, Cuyahoga and Rouge Rivers caught fire, and over 100 years for the Chicago River. The book investigates what has been accomplished, environmentally and ecologically, since those fires; what challenges remain; what lessons have been learned; how the fires catalyzed river cleanup; what institutional arrangements have been developed to clean and protect the rivers. More widely, what hope does the restoration of these rivers provide for others throughout the world; and what can be learned to help inspire and teach the next generation of environmentalists, conservationists and sustainability entrepreneurs?

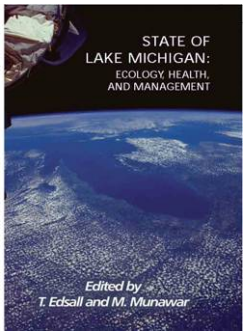


Checking the Pulse of Lake Erie

(2008. 640 pages, 115 figures, 104 tables, indices)

"The progress of research on Lake Erie has been marked by several milestone publications during the long struggle to restore the system. "Checking the Pulse of Lake Erie" is an important and excellent update and useful benchmark in the Lake Erie historical record. It contains 20 manuscripts contributed by almost 50 authors from a broad spectrum of disciplines and research interests."

- Ed Mills, Professor. Department of Natural Resources, Cornell University Biological Field Station.
- Joe Leach, Emeritus Scientist, Ontario Ministry of Natural Resources.



State of Lake Michigan: Ecology, Health & Management

(2005. 639 pages, 153 figures, 28 tables, indices)

"My hope is that we will not forget the lessons of three critical decades –the 1960s to the 1980s– when science based information, an ethic of concern for our shared environment and progressive bipartisan politics arrested and reversed a century of Great Lakes deterioration. This volume, cataloguing and analyzing the current science on the state of Lake Michigan, is an important part of that remembrance. It carries forward the singular contribution that the binational Great Lakes scientific community has made not only to restoring the Great Lakes, but also to the world's body of knowledge about large lake ecology, the long-range transport of pollutants, and the importance of habitat in assuring ecosystem health. It is a valuable addition to the Great Lakes literature."

- Lana Pollack, President, Michigan Environmental Council.

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